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SMOOTH-AWNED BARLEY VARIETIES[1]

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INTRODUCTION

Within the last decade a number of approved smooth-awned varieties of barley have become available to American and Canadian farmers. Prior to 1912 breeding work with bearded varieties was confined to the selection and crossing of rough-awned sorts. Although a number of excellent types were developed, they possessed the objectionable barbed awns. The substitution of hooded and hulless types for bearded forms did not prove altogether satisfactory, as the former were generally inferior in yielding capacity and tended to shatter readily.

Investigators have shown that the awns of the barley spike are important as transpiratory organs (*7*, *8*, *12*). Zoebl and Mikosch, cited by Hayes and Wilcox (*12*), worked with both two- and six-rowed barley and compared the transpiration rate of awned spikes and spikes with awns removed. They found the normal spikes to give off four to five times more water than the spikes with the awns removed. Perlitius, also cited by Hayes and Wilcox (*12*), found that transpiration was reduced 75% in the case of barley when awns were removed. Harlan and Anthony (*7*) found that, in addition to serving as transpiratory organs, the awns of barley serve as a depository for minerals. These investigators compared the daily development of clipped spikes with that of normal spikes. The awns of the normal spikes were found to contain 30% ash at maturity. In the case of clipped spikes the extra ash materials were probably deposited in the rachis. This deposition of ash caused the spikes to become brittle and prone to breaking. They believed their results could be used to explain the characteristic brittleness of the spikes of hooded and awnless barley varieties. Hayes and Wilcox (*12*) found that smooth-awned barleys were not handicapped physiologically in so far as transpiration capacity was concerned.

In wheat, certain workers have reported positive, others negative, and still others no relationship existing between the presence of awns and grain yield (*3*).

Harlan (*6*) first pointed out the economic advantages of smooth-awned varieties of barley. He believed that rough awns had limited the production of the barley crop, both through the added inconvenience they cause during harvesting and threshing, and their injurious nature when

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the straw is fed to livestock. Harlan (*6*) must also be credited for initiating the first smooth awn barley breeding programme in America.

VARIETAL TESTS

The breeding of smooth-awned barleys was greatly stimulated in the years 1913–17, when two black, smooth-awned varieties imported from Russia were distributed to different experiment stations in the United States and Canada, by the Office of Cereal Investigations, United States Department of Agriculture (*6*). As a result of this early work several experiment stations have now introduced smooth-awned barley varieties comparing favourably in agronomic characteristics with the more improved rough-awned sorts.

In the smooth awn barley breeding work at the Minnesota Experiment Station special attention was given to the selection of strains resistant to the spot blotch disease caused by *Helminthosporium sativum* (*11*, *13*). As a result, that station has introduced several smooth-awned varieties, including the well-known Glabron, Velvet and Comfort varieties which are resistant to this disease (*11*). The Michigan station has developed a smooth-awned, two-rowed, stiff-strawed variety known as Spartan (*5*). Resistance to the stripe disease caused by *Helminthosporium gramineum* has been combined with smooth awn in the variety Wisconsin Barbless No. 38, introduced by the Wisconsin Agricultural Experiment Station (*17*). The University of Saskatchewan at Saskatoon, Saskatchewan, has developed the variety Regal, from selections received from the Minnesota Experiment Station (*9*). It has a stiff straw and appears to be especially well adapted to Saskatchewan conditions.

The University of Alberta at Edmonton, Alberta, is at the present time increasing seed for distribution of a smooth-awned hybrid selection named Newal (H-19-146), which has shown great promise in recent varietal trials (*1*). This variety was developed from a cross made in 1919 between a white, six-rowed, smooth-awned selection (from a Manchurian × Lion cross) obtained from the Minnesota Agricultural Experiment Station, and a six-rowed rough-awned variety, O.A.C. No. 21. The latter is probably the most widely grown six-row barley variety in western Canada, and is generally favored by maltsters (*10*).

The above mentioned smooth-awned barley varieties have been included in barley varietal tests conducted at the University of Alberta for the period 1930–34. Data have been gathered on yield, earliness, strength of straw, height, weight per bushel and disease reaction. Each of these characters will be discussed in detail.

All of the regular varietal tests were conducted in systematically distributed quadruplicated rod-row plots. Each plot consisted of three rows one foot apart. The ends of the rows were trimmed off before harvest. The grain from the centre row was used for yield determinations and that from the border rows for malting tests.

Yield

Three of the recommended varieties for Alberta were included in the test for comparison. These were Trebi and O.A.C. No. 21, six-rowed, rough-awned varieties, and Canadian Thorpe, a rough-awned, two-rowed variety.

The available yield data for the five-year period 1930–1934 are summarized in Table 1. Both the four-year and five-year averages have been expressed as a percentage of the yield of O.A.C. No. 21. Newal shows the highest averages of the smooth-awned varieties tested, and outyields O.A.C. No. 21 by 8% for the five-year period. Comfort and Regal compare favourably with O.A.C. No. 21, yielding in the four-year average (1930–33) 97 and 95% of the latter respectively. Glabron, Velvet and Spartan are distinctly inferior in yielding capacity to O.A.C. No. 21. Spartan, a two-rowed, smooth-awned barley yielded several bushels less than the rough-awned, Canadian Thorpe. For the 1932-33 period Wisconsin Barbless No. 38 appears to rank with Comfort and Regal in yielding capacity.

Owing to the popularity of the smooth-awned type of barley and the demand for definite information regarding suitability to various parts of the country, arrangements were made by the Cereal Division of the Central Experimental Farm, Ottawa, and the National Barley Committee, in the spring of 1934, for a co-operative barley nursery at Edmonton to test

TABLE 1.—COMPARATIVE YEARLY (1930–34) AND AVERAGE YIELDS OF ROUGH- AND SMOOTH-AWNED VARIETIES WHEN GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Yield in bushels per acre								
		1930	1931	1932	1933	1934	4-year* average 1930–33	4-year average in % of O.A.C. No. 21	5-year† average 1930–34	5-year average in % of O.A.C. No. 21
O.A.C. No. 21	734	36.5	56.8	50.5	44.7	66.5	47.1	100	51.0	100
Trebi	753	32.7	54.9	59.1	37.5	78.0	46.0	98	52.2	102
Canadian Thorpe	816	11.0	50.0	44.5	34.8	40.0	35.1	75	36.1	71
Comfort	712	35.8	52.4	47.4	47.1	—	45.7	97	—	—
Glabron	718	29.0	49.3	43.4	39.5	50.2	40.3	86	42.6	84
Newal	1089	43.5	63.9	53.2	40.7	73.5	50.3	107	55.0	108
Regal	742	34.7	54.9	46.6	42.9	67.5	44.8	95	49.3	97
Spartan	860	22.5	43.9	33.4	31.5	49.0	32.8	70	36.1	71
Velvet	755	22.0	52.4	41.3	42.9	—	39.7	84	—	—
Wisconsin Barbless No. 38	758	—	—	48.9	41.5	—	—	—	—	—

*Standard error of the mean yield of a single variety for the four-year period, 1930–33, is 1.76 bushels. Significant difference between the means of any two varieties is 5.29 bushels.

†Standard error of the mean yield of a single variety for the five-year period, 1930–34, is 1.61 bushels. Significant difference between the means of any two varieties is 4.83 bushels.

the smooth-awned barley varieties, together with a few of the standard rough-awned sorts. In these tests the quadruplicated plots were distributed at random, but in all other respects were handled similarly to the regular varietal test plots. In Table 2 is given a summary of the data obtained from these co-operative smooth awn nursery tests.

With regard to yield, it will be seen that Newal exceeded all other varieties under test. The standard error of the mean of a single variety for this experiment was 4.75 bushels. Hence varietal differences exceeding three times this figure, or 14.25 bushels, may be judged significant. On this basis Newal significantly exceeds all varieties with the exception of Trebi. Regal shows significant increases over Comfort, Glabron and velvet, but does not significantly exceed Wisconsin Barbless No. 38.

Earliness of Maturity

Earliness of maturity is an important characteristic of any variety developed for northerly regions. It has an added significance in the case of barley, since this cereal is often sown late as a cleaning crop. From the data given in Table 3 it will be seen that there is little difference in the matter of earliness between the smooth-awned varieties tested. On the basis of the four-year (1930–33) average a spread of only three days exists

TABLE 2.—SUMMARY OF DATA FROM THE CO-OPERATIVE SMOOTH AWN BARLEY NURSERY AT THE UNIVERSITY OF ALBERTA, EDMONTON, 1934

Variety	Canadian accession number	Growth period in days	Percentage lodged	Height in inches	Weight per bushel in pounds	Average yield* in bushels per acre
Brandon 1099	1106	90	29	45	49.5	66.5
Brandon 2131	1110	90	11	46	49.0	58.5
Comfort	1107	90	16	49	45.5	56.5
Glabron	1093	88	6	48	50.0	56.5
Hannchen	1109	89	22	39	55.0	62.5
Newal	1089	85	3	45	52.0	88.0
Nobarb	1022	91	17	43	51.0	61.5
O.A.C. No. 21	1086	86	10	48	48.0	70.0
Ottawa 1014 E.25	1105	84	17	46	48.5	49.0
Regal	742	89	7	45	51.5	73.0
Sanalta	1088	91	4	44	52.0	70.0
Sans Barb 2	1074	87	19	45	48.5	71.5
Sans Barb 3	746	97	52	42	48.0	56.5
Trebi	1108	87	14	41	45.5	82.0
Velvet	1102	87	12	47	47.5	56.5
Wisconsin Barbless No. 38	1101	90	21	47	47.5	60.0

*Standard error of the mean of a single variety computed by the analysis of variance method = 4.75 bushels. The significant difference between the means of two varieties is 14.25 bushels.

TABLE 3.—COMPARATIVE YEARLY (1930–34) AND AVERAGE GROWTH PERIODS OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY, GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Growth period in days*								
		1930	1931	1932	1933	1934	4-year average 1930–33	No. of days + or − O.A.C. No. 21 4-year av.	5-year average 1930–34	No. of days + or − O.A.C. No. 21 5-year av.
O.A.C. No. 21	734	84	104	82	77	85	87	0	86	0
Trebi	753	85	109	84	77	87	89	+2	88	+2
Canadian Thorpe	816	93	106	89	85	97	93	+6	94	+8
Comfort	712	88	108	86	78	–	90	+3	—	—
Glabron	718	85	107	85	78	88	89	+2	89	+3
Newal	1089	86	106	84	77	86	88	+1	88	+2
Regal	742	87	104	85	78	88	89	+2	88	+2
Spartan	860	80	105	86	77	90	87	0	88	+2
Velvet	755	85	105	85	78	–	88	+1	—	—
Wisconsin Barbless No. 38	758	–	–	85	82	–	—	—	—	—

*Growth period is the number of days from emergence of seedlings to maturity.

between the earliest variety, Spartan, and the latest, Comfort. As Spartan is equal in average growth period with O.A.C. No. 21 and two days earlier than Trebi, it is evident that the smooth-awned varieties as a group compare favourably with the rough-awned varieties Trebi and O.A.C. No. 21 in earliness of maturity. Canadian Thorpe is, however, 6 days later than Spartan. The five-year averages (1930-34) show the varieties Newal, Regal and Spartan to be equal in growth period with Trebi and only two days later than O.A.C. No. 21. Glabron averaged three days later than the latter.

In the smooth-awned co-operative nursery at Edmonton in 1934 there was a difference between the earliest and latest maturing varieties of 13 days (See Table 2). Ottawa 1014 matured in 84 days and Newal in 85 days, while Sans Barb No. 3 required 97 days. It will be noted that the rough-awned varieties O.A.C. No. 21 and Trebi required respectively 86 and 87 days.

Strength of Straw

Strength of straw is of great importance in a barley variety. Not only is the yield of a lodged field greatly reduced, but the difficulties of harvesting are increased. The data in Table 4 show the comparative lodging of the varieties grown in the test. Percentage lodging was calculated by multiplying the percentage of plants lodged by the degrees off the vertical and dividing the product by 90. All of the smooth-awned varieties tested show a more desirable strength of straw than the rough-awned, six-rowed

TABLE 4.—COMPARATIVE YEARLY (1931–34) AND AVERAGE LODGING OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Lodging in per cent					
		1931	1932	1933	1934	Average 1931–33	Average 1931–34
O.A.C. No. 21	734	32	1	14	5	16	13
Trebi	753	52	1	5	14	19	18
Canadian Thorpe	816	0	1	0	0	0	1
Comfort	712	8	1	4	—	4	—
Glabron	718	14	0	2	6	5	6
Newal	1089	19	0	2	5	7	7
Regal	742	22	0	1	8	8	8
Spartan	860	2	0	1	3	1	2
Velvet	752	19	1	4	—	8	—
Wisconsin Barbless No. 38	758	—	1	4	—	—	—

varieties O.A.C. No. 21 and Trebi. Spartan appears to possess a particularly stiff straw and compares favourably in this respect with Canadian Thorpe. Comfort and Glabron show perhaps slightly less lodging on the three-year average (1931–33) than Regal, Velvet or Newal.

In the co-operative test in 1934 there were marked differences in lodging (Table II). Newal, Sanalta, Glabron and Regal were only slightly lodged, Sans Barb No. 3 badly lodged and the balance of the varieties only moderately so.

Height of Plant

Generally the length of straw of a barley variety is not considered an important character provided it is not so short as to complicate harvesting. Since the straw of the smooth-awned barleys will in all probability be used to a greater extent as greenfeed than has been the case with rough-awned varieties, a good length of straw consistent with good strength would be a desirable feature. The smooth-awned varieties under discussion all possess a satisfactory length of straw (Table 5). For the period 1930–33, Glabron and Velvet were equal to O.A.C. No. 21, while Newal, Regal and Spartan averaged from two to three inches shorter. Trebi averaged five inches shorter than O.A.C. No. 21 for the same period. From the summarized data obtained from the co-operative test in 1934, it is evident that a similar relationship exists (Table 2.)

Table 5.—Comparative yearly (1930–34) and average heights of rough- and smooth-awned barleys grown at the University of Alberta, Edmonton

Variety	Canadian accession number	Height in inches								
		1930	1931	1932	1933	1934	4-year average 1930–33	No. of inches + or − O.A.C. No. 21 for 4-year average 1930–33	5-year average 1930–34	No. of inches + or − O.A.C. No. 21 for 5-year average 1930–34
O.A.C. No. 21	734	32	44	40	37	47	38	0	40	0
Trebi	753	32	41	31	26	41	33	−5	34	−6
Canadian Thorpe	816	28	48	44	30	43	38	0	39	−1
Comfort	712	30	42	40	34	–	37	−1	—	—
Glabron	718	32	44	44	34	50	38	0	41	+1
Newal	1089	29	40	38	33	47	35	−3	37	−3
Regal	742	27	40	41	31	46	35	−3	37	−3
Spartan	860	32	42	38	31	43	36	−2	37	−3
Velvet	755	31	43	43	36	–	38	0	—	—
Wisconsin Barbless No. 38	758	–	–	41	35	–	—	—	—	—

Weight per Bushel

A high weight per bushel is to be desired in a barley variety as it denotes plumpness of kernel and a low percentage of hull. From the data given in Table 6 it is evident that all the six-rowed, smooth-awned varieties tested, with the possible exception of Wisconsin Barbless No. 38, show satisfactory weights per bushel as compared with O.A.C. No. 21 and Trebi. From the available data Wisconsin Barbless appears to be slightly inferior in this respect.

Newal ranked highest in weight per bushel of the six-rowed varieties tested. For the four-year period 1931–34 this variety averaged 51 pounds per bushel, as compared with 48.5 and 47.5 pounds shown by O.A.C. No. 21 and Trebi, respectively. It is of interest to note that Newal equalled the two-rowed Canadian Thorpe in this regard. Glabron and Regal both averaged 50 pounds per bushel, or one pound less than Newal.

The two-rowed, smooth-awned variety, Spartan, exceeded Canadian Thorpe by one and a half pounds on the four-year average.

The exceptionally high weight per bushel of Newal is again demonstrated by the results of the co-operative test (Table 2). In this test, Newal possessed the highest weight per bushel of the six-rowed varieties. With the exceptions of Comfort, Velvet and Wisconsin Barbless No. 38, all smooth-awned varieties tested either equalled or exceeded O.A.C. No. 21 in weight per bushel. Comfort showed a weight of only 45.5 pounds as compared with 48 pounds in the case of O.A.C. No. 21. Velvet and Wisconsin Barbless No. 38 each weighed 47.5 pounds per bushel.

TABLE 6.—COMPARATIVE YEARLY (1930–34) AND AVERAGE WEIGHTS PER BUSHEL OF ROUGH- AND SMOOTH-AWNED VARIETIES OF BARLEY GROWN AT THE UNIVERSITY OF ALBERTA, EDMONTON

Variety	Canadian accession number	Pounds per bushel						
		1930	1931	1932	1933	1934	3-year average 1931–33	4-year average 1931–34
O.A.C. No. 21	734	54.0	47.5	52.5	46.5	46.8	49.0	48.5
Trebi	753	50.0	44.0	51.5	46.0	47.5	47.0	47.5
Canadian Thorpe	816	—	53.0	54.0	47.0	50.5	51.5	51.0
Comfort	712	54.5	47.5	53.5	48.5	—	49.5	—
Glabron	718	54.0	47.0	52.5	49.0	51.0	49.5	50.0
Newal	1089	54.5	48.0	54.0	50.5	51.0	51.0	51.0
Regal	742	52.5	47.0	53.5	48.5	50.5	49.5	50.0
Spartan	860	—	52.5	54.0	51.5	52.0	52.5	52.5
Velvet	755	—	48.5	51.5	47.5	—	49.0	—
Wisconsin Barbless No. 38	759	—	—	50.5	45.5	—	—	—

Disease Reaction

Most varieties of barley are susceptible to one or more of the important diseases which affect the barley crop. The well-known rough-awned variety Trebi, which shows resistance to the stripe disease (*H. gramineum*) (*4*), is susceptible to the spot blotch disease (*H. sativum*) and the covered smut disease (*Ustilago hordei*) (*2, 18*). Hannchen and Canadian Thorpe exhibit considerable susceptibility to covered smut (*2*). Peatland, resistant to certain forms of rust (*16*), and Manchuria, resistant to spot blotch (*18*), are both susceptible to the stripe disease (*4*). Peatland is also moderately susceptible to covered smut (*2*). Smooth-awned varieties are no exception with regard to disease reaction. Some of the most promising varieties show susceptibility to a number of the common barley diseases. Thus, Newal and Comfort show considerable susceptibility to the covered smut disease (*2*), while Velvet is highly susceptible and Glabron moderately susceptible to the stripe disease (*4*). Furthermore, investigators generally have noted that smooth-awned varieties are susceptible to the loose smut disease. Both Regal and Wisconsin Barbless No. 38 have been reported as being susceptible to this disease (*9, 17*).

In view of these observations, it is evident that there exists a need for co-ordinating work on smooth awn with that of disease resistance in order to insure obtaining the most desirable strains. Working on this

basis, the Minnesota Agricultural Experiment Station has introduced the varieties Glabron, Velvet and Comfort in which smooth awn has been combined with resistance to the spot blotch disease (*H. sativum*) (*11, 13*). Similarly, resistance to the stripe disease (*H. gramineum*) has been incorporated into the variety Wisconsin Barbless No. 38, by workers at the Wisconsin Agricultural Experiment Station (*17*).

In both varietal and breeding investigations with smooth-awned barleys, conducted at the University of Alberta, the problem of disease resistance has been a prime consideration. Both covered smut and stripe reaction were studied in a cross involving a smooth-awned variety as one parent (*14, 15*). Later generations of smooth-awned, resistant selections obtained from this cross are now being compared with standard varieties.

From the results of covered smut tests conducted during the years 1931, 1932, and 1934, Glabron, Velvet and Wisconsin Barbless No. 38 appear to be highly resistant, Regal and Spartan moderately resistant and Newal and Comfort moderately susceptible (*2*).

In 1930, the spikes of a number of barley varieties were dusted at flowering time with chlamydospores of the loose smut fungus (*Ustilago nuda*). The inoculated spikes were enclosed in glassine bags after inoculation and sprayed at intervals with a spore suspension of the fungus. The inoculated seed was sown in the spring of 1931. The infection percentages of the smooth-awned varieties tested are given in Table 7.

TABLE 7.—REACTION OF SIX SMOOTH-AWNED VARIETIES OF BARLEY TO INFECTION WITH THE LOOSE SMUT AND STRIPE DISEASES

Variety	Canadian accession number	Percentage of plants infected			
		Loose smut	Stripe		
		1931	1931	1932	Average
Comfort	712	9	2	3	3
Glabron	718	3	7	0	4
Newal	1089	11	0	0	0
Regal	742	3	9	0	5
Spartan	860	3	0	0	0
Velvet	755	2	24	17	20

Infection was generally low, the only varieties showing even moderate susceptibility being Comfort and Newal. However, observations of natural infections occurring in the varietal plots for the period 1931–34, showed that all of the smooth-awned varieties under discussion were generally susceptible to this disease.

The infection percentages of stripe disease observed on these varieties in the years 1931 and 1932 are also contained in Table 7. The varieties in question were sprayed several times at flowering with a wet conidial suspension of the stripe organism. While the infection percentages are low, the susceptibility of Velvet to this disease is evident. The infection percentages obtained in 1931 show Glabron and Regal to be somewhat susceptible. No infected plants were found in the varieties Newal and

Spartan. Glabron showed infection percentages ranging from 5–25% when used as a parent in the breeding studies referred to above (*15*).

SUMMARY

Data are presented on the agronomic behavior and disease reaction of a number of promising smooth-awned varieties of barley grown at the University of Alberta, Edmonton, for the five-year period, 1930–34. Generally the smooth-awned barley varieties compared quite favourably with the rough-awned varieties O.A.C. No. 21 and Trebi. The smooth-awned varieties as a group possessed a much stronger straw than the latter, and equalled them in length of straw and earliness of maturity.

In yield and weight per bushel, Newal ranked highest of the smooth-awned, six-rowed varieties tested, and also excelled O.A.C. No. 21 and Trebi in these respects. Comfort and Regal compared quite favourably with O.A.C. No. 21 in yielding capacity and weight per bushel. Glabron and Velvet proved to be inferior to the other six-rowed, smooth-awned varieties tested in yielding capacity but showed satisfactory weights per bushel. From the limited data available, Wisconsin Barbless No. 38 appeared to rank with Comfort and Regal in yielding capacity. This variety, however, possessed the lowest weight per bushel of the varieties tested.

The two-rowed, smooth-awned variety, Spartan, possessed an exceptionally stiff straw and high weight per bushel. It was also one of the earlier maturing varieties, averaging six days earlier than the two-rowed, rough-awned variety, Canadian Thorpe. However, the latter variety was superior in yielding capacity.

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Résumé

Variétés d'orge à barbe lisse. O. S. Aamodt et W. H. Johnston, Université de l'Alberta, Edmonton, Alta.

Le comportement agronomique et la résistance aux maladies d'un certain nombre de variétés d'orge promettantes, à barbe lisse, cultivées à l'Université de l'Alberta, Edmonton, pendant les cinq années de 1930-34, sont l'objet de cette étude. En général les variétés d'orge à barbe lisse ont soutenu très avantageusement la comparaison avec les variétés à barbe rude O.A.C. No. 21 et Trebi. En tant que groupe, les espèces à barbe lisse avaient une paille beaucoup plus forte que les autres et leur étaient égales quant à la longueur de la paille et à la précocité de maturité. Au point de vue du rendement et du poids par boisseau, l'orge Newall est venue première parmi les variétés à barbe lisse et à six rangs qui étaient à l'essai; elle a dépassé également la O.A.C. No. 21 et la Trebi sous ces rapports. Les orges Comfort et Regal soutenaient très avantageusement la comparaison avec la O.A.C. No. 21 en capacité de rendement et en poids par boisseau. Les Glabron et Velvet se sont montrées inférieures au point de vue du rendement aux autres espèces à barbe lisse et à six rangs, mais leur poids par boisseau était satisfaisant. A en juger par les données limitées qui ont été recueillies, la Wisconsin sans barbes No. 38 paraît être l'égale de la Comfort et de la Regal en capacité de rendement, mais cette variété est celle qui pesait le moins par boisseau de toutes les variétés à l'essai. L'orge Spartan à barbe lisse et à deux rangs, avait une paille exceptionnellement raide et un poids élevé par boisseau. C'était également l'une des plus précoces à mûrir; elle était en moyenne de six jours plus précoce que la Canadian Thorpe, une variété à barbe rude et à deux rangs, mais cette dernière lui était supérieure au point de vue du rendement.

STUDIES ON THE CONTROL OF ROOT-ROT DISEASES OF CEREALS CAUSED BY *FUSARIUM CULMORUM* (W.G. SM.) SACC. AND *HELMINTHOSPORIUM SATIVUM* P., K., AND B.

III. EFFECT OF SEED TREATMENT ON THE CONTROL OF ROOT ROT AND ON THE YIELD OF WHEAT[1]

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Treating cereal seed with fungicides to prevent certain seed-borne diseases has now become a well established agricultural practice, but comparatively little experimentation has been done to determine the effectiveness of seed treatment in preventing the development of soil-borne diseases of cereals, such as the common root rot caused by species of *Fusarium* and *Helminthosporium*. This disease is very common in Western Canada and causes annually considerable loss (*1*); and, as it tends to increase in severity in fields subjected to continued cropping with cereals, it is becoming one of the most destructive cereal diseases in the Prairie Provinces.

Greaney and Bailey (*3*) found that seed treatment with Semesan afforded protection to seedlings of wheat, oats, and barley against attacks by some common root-rotting fungi. Simmonds and Scott (*8*) reported that certain new organic mercury-compounds protected seedlings from attacks by *Fusarium culmorum* and *Helminthosporium sativum* in greenhouse tests. Leukel, Dickson, and Johnson (*6*) and O'Brien and Dennis (*7*), while themselves working with seed-borne diseases, gave an adequate resumé of other work with seed treatments in which soil-borne, root-rotting diseases of cereals were investigated.

The present paper gives the results of laboratory, greenhouse, and field studies, designed to determine the effect of various seed disinfectants on the control of the common root-rot disease of wheat caused by *Fusarium culmorum* (W.G. Sm.) Sacc. and *Helminthosporium sativum* P., K., and B.

LABORATORY AND GREENHOUSE EXPERIMENTS

The Relative Efficiency of Some Seed Disinfectants as Preventatives of "Seedling Blight" and Root Rot in Cereals

In this experiment the value of six different fungicides on four varieties of cereals was tested. The treatments included formaldehyde (one part of commercial Formalin to 320 parts of water), iodine-infusorial earth dust (containing 5% iodine by weight), nickel-sulphide dust, copper carbonate dust, Semesan and Ceresan. The fungicides, except formaldehyde, were applied to the seed as dusts. The rate of application for the dusts was 3 ounces (85.05 grams) per bushel (0.35239 hls.) of grain, except where wheat seed was treated with Ceresan, when the quantity of dust was reduced to 2 ounces (56.7 grams) per bushel. The seed treated with formaldehyde was steeped in the solution for one-half hour, then drained, and covered for 2 hours before sowing.

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The varieties of cereals included in the test were Marquis and Mindum wheats, Canadian Thorpe barley, and Banner oats. Treated and untreated seed lots of each variety were planted in sterile soil artificially infected with *F. culmorum*, and in sterile soil alone. The methods of soil sterilization, infestation, and planting of the seed have been described in a previous paper (*5*). Uniform conditions of moisture in the soil were maintained during the experiment. The plants were grown in a greenhouse of which the atmospheric temperature wàs maintained within the range 18–22° C. Two weeks from the date of seeding counts were made of the healthy and diseased seedlings. Table 1 summarizes the data of four trials.

TABLE 1.—EFFECT OF TREATING SEED WITH VARIOUS FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF CEREALS CAUSED BY *Fusarium culmorum*. (AVERAGE OF FOUR TRIALS WITH FOUR VARIETIES OF CEREALS.)

Fungicides	Soil Treatments			
	Control		Infested with *F. culmorum*	
	Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	%	%	%
Formalin Steep	81	38	14	100
Iodine-Infusorial earth	88	18	47	39
NiS dust	95	8	70	49
$CuCO_3$ dust	96	16	71	45
Ceresan	90	2	89	4
Semesan	97	2	96	8
Control	91	36	70	41

It will be seen from Table 1 that some of the seedlings grown in supposedly sterile soil showed root rot. This was caused by chance contamination of the soil after the seed was sown. In no case, however, was any perceptible harm done to these seedlings; whereas, many of the seedlings grown in artificially infested soil failed to emerge, and of those that did emerge, many died or wilted badly before the notes were taken. The results show that under the conditions of the experiment the organic mercurials, Ceresan and Semesan, were considerably more effective in controlling root rot in seedlings than the other fungicides used. Copper carbonate was relatively ineffective, while formaldehyde actually increased the severity of the disease.

As copper carbonate is widely used as a seed treatment to control bunt of wheat, some information was desired as to why it gave inadequate control of root rot. Laboratory experiments were therefore made to determine the relative value of copper carbonate as compared to Ceresan and Semesan as a preventative of spore germination and mycelial growth in the fungi *H. sativum* and *F. culmorum*.

In order that conditions for spore germination should be somewhat similar to those found in nature, the spores were germinated in soil extract to which the fungicides were added. The soil extract was prepared by

mixing one part of black-loam soil with two parts of distilled water, allowing the mixture to stand for six hours, and then decanting the supernatant fluid. This liquid was filtered and sterilized by autoclaving, and then allowed to cool. A calculated quantity of copper carbonate was added to a portion of the extract, and dilutions of the mixture were made by adding more extract according to need. Mixtures of each of the other two fungicides and the extract were similarly prepared, and dilutions were then made.

After the series of dilutions had been completed, drops of each dilution were placed on clean glass slides and inoculated with spores from a fresh culture of the fungus to be tested. The slides were then placed in moist chambers and incubated for 24 hours at room temperature. The average results of four tests with two fungi and six dilutions of each of the three fungicides are summarized in Table 2.

TABLE 2.—TOXICITY OF VARIOUS CONCENTRATIONS OF CERESAN, SEMESAN, AND COPPER CARBONATE TO SPORES OF *Fusarium culmorum* AND *Helminthosporium sativum*. (AVERAGE OF FOUR TRIALS.)

Dilution of fungicides	Spore germination classes*					
	H. sativum			*F. culmorum*		
	Ceresan	Semesan	$CuCO_3$	Ceresan	Semesan	$CuCO_3$
Control	5	5	5	5	5	5
1–100,000	4	3	3	3	2	3
1– 80,000	4	3	2	2	2	3
1– 60,000	4	3	2	2	1	3
1– 40,000	2	2	1	1	1	3
1– 20,000	0	0	1	0	0	2
1– 10,000	0	0	1	0	0	2

*Class value	Range of germination percentages	Class value	Range of germination percentages
0	0	3	41–60
1	1–20	4	61–40
2	21–40	5	81–100

It is seen in Table 2 that Semesan and Ceresan completely prevented spore germination at 1–20,000 dilution while copper carbonate did not. The greater toxicity of the organic mercurials was further demonstrated through the fact that germtubes formed in solutions of these fungicides were generally very short, while those formed in the presence of copper carbonate grew almost as long as those in the controls.

The effect of the three fungicides on the mycelial growth of *H. sativum* and *F. culmorum* was also determined. Various soil extract and fungicide mixtures were prepared as in the spore-germination tests. To each dilution was added Difco potato-dextrose agar at the rate of 40 grams per litre. This provided a solid medium containing soil extract, the desired dilution of a fungicide, and sufficient nutrients to allow good growth of mycelium. After sterilization the medium was poured in 15 c.c. lots into sterile Petri dishes. When cool each plate was inoculated with actively-growing mycelium of *H. sativum* or of *F. culmorum*. After inoculation, the dishes were placed in an incubator maintained at room temperature. Ten days

later the diameters of the individual cultures were measured. The average diameter of four cultures of each fungus on each of the different dilutions of fungicides are given in Table 3.

TABLE 3.—THE EFFECT OF DIFFERENT CONCENTRATIONS OF CERESANS SEMESAN, AND COPPER CARBONATE ON THE MYCELIAL GROWTH OF *Helminthosporium sativum* AND *Fusarium culmorum*. (AVERAGE DIAMETERS OF 4 TEN-DAY-OLD CULTURES.)

Dilution of fungicides	Diameter of culture in millimeters					
	H. sativum			*F. culmorum*		
	Ceresan	Semesan	$CuCO_3$	Ceresan	Semesan	$CuCO_3$
Control	50.5	50.0	50.6	150.1	156.0	150.3
1–100,000	50.0	50.0	50.9	140.2	133.0	150.3
1– 80,000	30.1	25.0	50.0	70.6	76.1	150.0
1– 60,000	10.3	15.3	50.8	30.0	35.0	145.9
1– 40,000	0.0	7.5	50.1	10.1	27.2	140.3
1– 20,000	0.0	5.4	50.6	2.0	7.5	140.3
1– 10,000	0.0	2.1	50.0	0.0	2.5	140.0

It is seen from Table 3 that both Semesan and Ceresan reduced or prevented mycelial growth of *H. sativum* and *F. culmorum* at dilutions where copper carbonate had little effect. Ceresan evidently was the more toxic of the two mercurials. These results, as well as those summarized in Table 2, indicate, to some extent at least, why Semesan and Ceresan were able to control common root rot in greenhouse experiments while copper carbonate did not. The mercury compounds are more toxic than copper carbonate to spores and mycelium of these two fungi, a fact which appears to account for the control of the disease after seed treatment with Ceresan and Semesan.

The Relative Efficiency of Some Fungicidal Steeps in the Control of "Seedling Blight" and Root Rot of Wheat

The object of these experiments was (a) to determine whether certain fungicides which are commonly applied to seed as dusts would also be useful as fungicides when used in liquid form, and (b) to determine the dilutions and periods of seed-immersion which could be used without injury to the seed.

In the first test the comparative efficiency of Ceresan and Semesan when applied as dusts or steeps to seed grain was investigated. The dusts were applied to the seed according to the directions of the manufacturers. The steeps were prepared by mixing each fungicide with water and diluting according to need. The steep was applied by dipping the seed for one of three different time intervals. In all cases the seed was planted within one hour after treatment, in sterile soil or soil artificially infested with *F. culmorum*. The pots of soil were then placed in a greenhouse maintained at a temperature range of 20–22° C. After two weeks notes on seedling emergence, seedling blight and root rot data were taken; these are summarized in Table 4.

TABLE 4.—THE EFFECT OF DUST AND STEEP TREATMENTS PREPARED FROM TWO FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF MARQUIS WHEAT CAUSED BY *Fusarium culmorum*. (AVERAGE OF 2 TRIALS.)

Treatment	Concentration of solution	Period of steep	Soil treatments: Control		Soil treatments: Infested with *F. culmorum*	
			Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	Minutes	%	%	%	%
Ceresan (Liquid)	5	1	93	1	90	5
" "	5	2	89	0	90	2
" "	5	5	70	0	68	0
" "	25	1	16	0	18	0
" "	25	2	4	0	5	0
" "	25	5	0	0	2	0
Ceresan (Dust)	—	—	100	0	97	3
Semesan (Liquid)	5	1	100	0	98	2
" "	5	2	97	0	97	2
" "	5	5	98	0	96	1
" "	25	1	81	0	90	2
" "	25	2	62	0	75	4
" "	25	5	45	0	55	1
Semesan (Dust)	—	—	99	1.5	99	6
Control	—	—	95	6	48	58

Table 4 shows that the dust treatments and the steep treatments (5% concentration of the fungicides and 2 minutes immersion of the seed) are almost equally effective in the control of root rot. Higher concentrations of the fungicides or longer periods of immersion may result in injury to the seed.

In a second test, made to study further the utility of steeps in root-rot control, four different fungicides were used. These fungicides, namely, Uspulun, Semesan, Ceresan, and New Improved Ceresan, were mixed separately with water to form steeps of 25%, 12.5%, 5.0% and 2.5% concentrations. Marquis wheat seed was immersed in the steep for 2 minutes, and then planted in sterile soil and in soil infested with *F. culmorum*. The plants were grown in a greenhouse maintained at a temperature of 20–22° C. After 14 days notes on the development of disease in the plants were taken. The results obtained from two separate trials are given in Table 5.

It is seen from Table 5 that good protection to the seedling from invasion by the root-rotting fungus, *F. culmorum*, was given by the lowest fungicide concentration used. At this concentration Semesan and New Improved Ceresan were the most effective, but as New Improved Ceresan caused some seed injury and Semesan did not, Semesan was considered the more desirable of the two. In all cases, however, good protection from root rot was afforded the seedlings by the steep, as indicated by the great difference in disease development found in treated and untreated plants grown in the infested soil.

TABLE 5.—EFFECT OF TREATING SEED WITH DIFFERENT CONCENTRATIONS OF FOUR FUNGICIDES ON THE DEVELOPMENT OF SEEDLING ROOT ROT OF WHEAT CAUSED BY *Fusarium culmorum*. (AVERAGE OF 2 TRIALS.)

Fungicides	Concentration of solution	Soil treatments			
		Control		Infested with *F. culmorum*	
		Plants emerged	Emerged plants diseased	Plants emerged	Emerged plants diseased
	%	%	%	%	%
Uspulun	25.0	82	0.0	89	7.8
"	12.5	89	1.1	85	3.5
"	5.0	95	2.1	91	7.7
"	2.5	100	0.0	85	16.4
Control	0.0	93	3.0	0	—
N. I. Ceresan	25.0	1	0.0	0	—
"	12.5	1	0.0	1	0.0
"	5.0	6	0.0	14	0.0
"	2.5	60	0.0	54	5.5
Control	0.0	95	3.2	3	100.0
Semesan	25.0	77	0.0	86	4.7
"	12.5	94	0.0	96	6.2
"	5.0	95	1.1	95	4.2
"	2.5	98	1.0	93	5.3
Control	0.0	97	2.1	0	—
Ceresan	25.0	2	0.0	6	0.0
"	12.5	30	0.0	39	2.5
"	5.0	85	0.0	84	4.7
"	2.5	98	0.0	84	13.1
Control	0.0	94	2.1	0	—

Effect of Seed Treatment on Seed and Seedling

It was observed throughout the preceding experiments that the exterior of the seed which had been treated with the organic mercury-compounds presented a fresh, bright appearance, even after the seed had remained two weeks in heavily infested soil and had produced a seedling several inches in height. The seed, however, by this time had lost considerable volume and sections of the remnant showed that only a small fraction of the original seed contents remained. All the endosperm had evidently been used as food for the growing plant. On the other hand, when the seed had been treated with copper carbonate, nickel sulphide, iodine-infusorial earth dust, or formaldehyde steep, it showed only partial preservation. Intreated seed, after remaining 14 days in infested soil, was as plump as before sowing, but was considerably discoloured and the contents had assumed a gelatinous nature. In the latter case the seed contents had been largely replaced by fungal hyphae which found ready access to the unprotected seed and an ample supply of nutrients in it for their use.

In the experiments dealing with different fungicides and methods of application it was seen, furthermore, that seedlings arising from seed which had received poor protection by seed treatment from fungal invasion

always developed more slowly than did seedlings from well-protected seed. These unprotected seedlings almost invariably became infected shortly after the seed had germinated, and wilted in most instances. The protected seedlings grew well and were relatively free from disease when they were pulled for examination.

When Ceresan or New Improved Ceresan was applied to the seed as a steep in concentrations higher than 5%, or when the length of the steep was greater than 2 minutes, the seed became damaged. Although such seed germinated, the coleoptile grew very slowly and became broad and bulbous in appearance. The extent of the deformity varied with the strength of the solutions, being very pronounced when the concentration was high.

Seed treated with formaldehyde and planted in infested soil remained relatively free itself from invasion by *F. culmorum*. The treatment appeared however, to have an adverse effect on the growth of the seedlings, thus predisposing them to the disease.

FIELD EXPERIMENTS

Extensive trials have been made by the writers during the three years 1932 to 1934 to determine the value of seed disinfection in the control of root rot of wheat caused by species of *Fusarium* and *Helminthosporium* under field conditions. The trials consisted of rod-row experiments and large-plot tests. To provide an adequate test of the relative fungicidal effectiveness of several competing seed disinfectants, the experiments were so arranged that the heterogeneity of the soil as well as the differences between the seed treatments could be accurately evaluated. Randomized Block and Latin Square plans of plot arrangement were used. The "analysis of variance" method, devised and described by Fisher (*2*), was used for analysing the data.

Rod-row Experiments

Dust and liquid preparations of Semesan, Ceresan, New Improved Ceresan, and copper carbonate were tested in 1932 and 1933. Dressings of Semesan and copper carbonate were applied at the rate of 3 ozs., Ceresan at 2 ozs., and New Improved Ceresan at ½ oz. per bushel of grain. For the liquid treatments, 0.5% water solutions of Ceresan, Semesan, New Improved Ceresan, and copper carbonate were prepared. The seed was placed in cheese-cloth bags and immersed for 2 minutes. The seed was then spread out on a clean cloth to dry. In 1934 the dust treatments used were as in the 1933 experiment, but the only liquid treatment tested was formaldehyde. For this wet treatment the seed was soaked for one-half hour in a solution of commercial Formalin (1 : 320), then drained, and afterwards kept covered for 2 hours. In all tests dry untreated seed, and seed soaked in water for 2 minutes were used as controls.

The general arrangement of the rod row experiments was as follows. The seed was planted in rod rows placed one foot apart, in adequately replicated blocks. Each block was divided into plots representing different seed treatments and the control. In order to insure a positive attack by root-rot fungi, one-half of each plot (a split-plot) was artificially infested with *F. culmorum*, while the other split-plot was not artificially infested

and thus served as a soil control. The disposition of the seed treatments and the soil treatments (artificially-infested and ordinary field soil) was purely at random within each block. Each split-plot consisted of two rod rows, in one of which the seed was spaced in the row (100 seeds per row) and in the other a weighed quantity of seed was distributed evenly. The field technique and methods of recording the amount of disease as described by Greaney and Machacek (*4*) were utilized in the present experiments. Plant-emergence, disease-rating, and yield data were treated by the "Analysis of Variance" and "*Z*" test (Fisher (*2*)).

Mindum and Marquis were the wheat varieties used in 1932. In 1933 and 1934 Mindum only was used. The seed was hand-selected but not scarified. The fungus selected for infesting the field plots was *Fusarium culmorum* (W.G. Sm.) Sacc. and the culture used was very pathogenic on wheat. The plots were artificially infested by applying at seed level in each rod row 600 c.c. of soil inoculum of *F. culmorum*.

In order to ascertain what significance may be attached to the disease rating as a true measure of the amount of injury caused by cereal root-rot fungi on wheat, disease ratings and yields of individual plots were correlated in these experiments. The significance of the coefficients of correlation was determined according to the method described by Fisher (*2*). The results of these analyses are presented in Table 6.

Table 6.—Coefficients of correlation between root-rot disease rating and yield of wheat

Year	Variety	Correlation coefficient	t*
1932	Mindum	−0.2916	2.69
1932	Marquis	−0.3541	3.34
1933	Mindum	−0.5420	7.66
1934	Mindum	−0.0744	0.72

*1% point = 2.57.

The t values for 1932 and 1933 exceed the 1% points and thus establish the significance of the coefficients. These results show that increases in the degree of infection caused by root-rot fungi result in decreases in the yield of wheat, and confirm the findings of Greaney and Machacek (*4*) that the disease rating constitutes a reliable measure of the amount of root-rot disease on wheat under field conditions. Thus, in examining the results obtained in 1932 and 1933, the disease rating was considered an accurate measure of the root-rot control secured through seed treatment. In 1934, owing probably to the exceedingly dry conditions which prevailed during the early part of the season, the disease rating was not significantly associated with yield.

Table 7 gives the complete analysis of variance for plant emergence, disease rating, and yield of the 1933 experiment, and illustrates the method of analysis utilized in all rod-row experiments reported in this paper.

The significance of the results of the experiment is assessed by the Z test, in which the variance due to any known cause is compared to the variance due to error. The Z values obtained for dust and liquid seed treatments in 1933 are not significant. Thus, as illustrated in Table 7, the values of Z for plant emergence, disease rating, and yield, for liquid and dust seed treatments are less than the values required for significance at the 5% levels. It may be concluded, therefore, that the differences

TABLE 7.—COMPLETE ANALYSIS OF VARIANCE FOR PLANT EMERGENCE, DISEASE RATING AND YIELD (SEED TREATMENT EXPERIMENT, 1933)

Plant Emergence

	Degrees of freedom	Sum of squares	Mean square	Z	5% point
Controlled error	8	2174.65	271.83		
Seed treatments	3	1770.03	590.01	0.9990	0.5117
Soil treatments	2	6084.18	3042.09	1.8191	0.5777
Seed treatments × soil treatments	6	2837.27	472.88		
Error (1)	52	4177.85	80.34		
Dusts and liquids	1	72.25	72.25	0.3113	0.6933
Dusts and liquids × seed treatments	3	469.47	156.49		
Dusts and liquids × soil treatments	2	14.29	7.14		
Interaction (second order)	6	40.16	6.69		
Error (2)	60	2325.83	38.75		
Total	143	19965.98			

Disease Rating

	Degrees of freedom	Sum of squares	Mean square	Z	5% point
Controlled error	8	1512.81	189.10		
Seed treatments	3	422.26	140.75	0.6536	0.5117
Soil treatments	2	3774.06	1887.03	1.9516	0.5777
Seed treatments × soil treatments	6	1420.20	236.70		
Error (1)	52	2026.07	38.96		
Dusts and liquids	1	56.78	56.78	0.3381	0.6933
Dusts and liquids × seed treatments	3	263.07	87.69		
Dusts and liquids × soil treatments	2	7.09	3.54		
Interaction (second order)	6	38.35	6.39		
Error (2)	60	1549.87	25.83		
Total	143	11070.56			

Yield (Bushels per acre)

	Degrees of freedom	Sum of squares	Mean square	Z	5% point
Controlled error	8	3232.29	404.04		
Seed treatments	3	52.60	17.53	—	—
Soil treatments	2	422.39	211.19	1.1116	0.5777
Seed treatments × soil treatments	6	413.36	68.90		
Error (1)	52	1189.07	22.86		
Dusts and liquids	1	1.73	1.73	—	—
Dusts and liquids × seed treatments	3	164.53	54.84		
Dusts and liquids × soil treatments	2	14.33	7.16		
Interaction (second order)	6	34.39	5.73		
Error (2)	60	632.03	10.53		
Total	143	6156.82			

observed between liquid and dust treatments are not significant ones. The analysis therefore establish the fact that, as far as seed treatments for root-rot control are concerned, the dusts were just as effective as the

liquids. Consequently, in presenting the results of individual fungicides used in these field experiments, the average results of dust and liquid treatments are given.

The values of Z for soil treatments (soil artificially infested and ordinary field soil) in Table 7 greatly exceed the 5% points, and indicate that a high degree of significance can be attached to the differences in soil treatments in this experiment. From the results it may be assumed that the differences observed in plant emergence, disease rating, and yield were due to positive attacks of cereal root-rot fungi. The importance of establishing significant differences between soil treatments in experiments with root-rot diseases of cereals has already been discussed (*4*).

Examination of Table 7 shows that the Z values for seed treatments, plant emergence, and disease rating are highly significant. In order, however, to establish beyond question the practical value of any given disinfectant, it is necessary to obtain significant differences between yields derived from the various treatments under field conditions.

The analysis of the complete results obtained from rod-row seed treatment experiments of 1932 and 1934 established significant differences in plant emergence and disease rating, and the analysis of the 1934 data indicated, in addition, differences in yields beyond the limit set for significance. When the significance of seed and soil treatment differences had been established, a detailed examination of the results was made. The standard error of the means of treatments and the complete results of the three years' experiments are summarized in Table 8.

TABLE 8.—EFFECT OF TREATING SEED WITH CERESAN, SEMESAN, NEW IMPROVED CERESAN, COPPER CARBONATE AND FORMALIN ON PLANT EMERGENCE, ROOT-ROT DISEASE RATING AND YIELD OF MINDUM WHEAT. RESULTS OF ROD-ROW TESTS AT WINNIPEG, MAN., IN 1932, 1933 AND 1934.

Year		Ceresan	Semesan	New Imp. Ceresan	Copper carbonate	Formal-dehyde	No. treatment	Standard error*
1932	Plant emergence (%)	55.4	54.8	56.2	50.9	—	47.2	1.41
	Disease rating	66.2	65.7	64.7	68.8	—	71.1	0.89
	Yield (Bu. per ac.)	23.7	24.9	24.0	23.2	—	22.9	—
1933	Plant emergence (%)	64.2	—	63.1	57.8	—	55.9	1.49
	Disease rating	65.3	—	66.2	68.1	—	69.7	1.04
	Yield (Bu. per ac.)	18.5	—	17.3	18.2	—	17.0	—
1934	Plant emergence (%)	84.0	81.5	83.3	76.9	59.7	77.7	1.37
	Disease rating	46.1	46.2	44.0	49.8	59.1	48.0	1.12
	Yield (Bu. per ac.)	30.1	32.1	32.9	33.7	21.3	30.5	1.95

*Differences between means required for significance = Standard error $\times 2 \sqrt{2}$

The results in Table 8 show that although significant differences in plant emergence and disease rating occur, thus indicating the effectiveness of individual seed treatments, these are not always accompanied by significant yield differences.

In each year, seed treated with Ceresan, Semesan or New Improved Ceresan germinated better than untreated seed, and the amount of root

rot was reduced by seed disinfection to a significant degree. Copper carbonate did not influence seed germination, and it was inferior to the organic mercurials in reducing the incidence of root rot. In 1934 seed treatment with formaldehyde reduced emergence to such a degree that yield was significantly below that of the control, while the disease rating was considerably higher.

In general the results obtained during the three years, on soil infested with *H. sativum* and *F. culmorum*, confirm the findings of Simmonds and Scott (*9*), Bailey and Greaney (*3*), and others, and show that wheat seed disinfected with certain organic mercury-compounds germinates better than seed left untreated, or treated with copper carbonate or formaldehyde. The yield of wheat, however, was not constantly and significantly influenced by seed treatment.

Large-plot Tests

The large-plot tests were made at Winnipeg in 1932 and 1933, and at Winnipeg and Brunkild, Man., in 1934. The fields chosen for the tests consisted of fall-ploughed clay-loam soil which had been cropped the preceding year with wheat. These fields were naturally infested with the common cereal root-rotting fungi, the Brunkild field being selected particularly on account of the prevalence of *Helminthosporium sativum* in the soil.

Dust and liquid seed treatments consisting of Ceresan, Semesan, New Improved Ceresan, and copper carbonate were tested in 1932 and 1933 on Marquis and Mindum wheat. In 1934 Mindum only was used. The seed was treated in large lots a short time before seeding. The methods and rates of fungicide applications were similar to those used in the rod-row experiments.

The Latin Square method of plot arrangement was used. The seed was sown in 1/200th acre plots by means of an ordinary grain drill. Alleys, 3 feet in width, separated the plots. At harvest time, the border rows were removed, and the grain of each plot was harvested and threshed separately to obtain yield data. The methods of seed treatment and soil management were very similar to those employed in ordinary agricultural practice.

The intensity of root rot in individual plots was not recorded in 1932 and 1933. The plots, however, were watched closely during the growing season, and the general development of disease was observed from time to time. In 1934, however, a disease rating expressing the amount of root rot was determined for each plot.

The large-plot tests were designed to determine the effect of seed treatment on yield of wheat. Examination of the yield results of the different experiments indicated that a real effect due to different seed treatments was being studied. In order to determine whether the yields were of significant value a thorough analysis of the data was made. Fisher's analysis of variance method was adopted for this purpose. This method permits an evaluation of the experiment as a whole, as well as of the individual treatments. Table 9 gives the analysis of variance for yield of two Latin Square experiments made at Winnipeg in 1932.

TABLE 9.—ANALYSIS OF VARIANCE FOR YIELD OF MINDUM AND MARQUIS WHEAT. LATIN SQUARE SEED-TREATMENT EXPERIMENTS, 1932

Marquis

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5% point
Rows	7	1760.60	251.51		
Columns	7	741.80	105.90		
Liquids and dusts	1	42.09	42.09	0.0244	0.6923
Seed treatments	3	415.44	138.49	1.5070	0.4017
Liquids and dusts × seed treatments	3	69.93	23.31		
Error	42	735.37	17.50		
Total	63	3765.23			

Mindum

Source of variance	Degrees of freedom	Sum of squares	Variance	Z	5% point
Rows	7	1880.86	268.69		
Columns	7	795.41	113.63		
Liquids and dusts	1	10.48	10.48	—	—
Seed treatments	3	295.63	98.54	0.6826	0.4017
Liquids and dusts × seed treatments	3	204.48	68.16		
Error	42	1057.13	25.16		
Total	63	4243.99			

The analysis in Table 9 establishes the significance of seed treatment differences, but no significant difference is shown between the dust and liquid fungicide application. The 1932 results with Marquis and Mindum wheat were confirmed in 1933. The evidence supports the conclusions drawn from the rod-row tests, and shows that the dust and the liquid fungicides were equally satisfactory as a means of controlling root rot in wheat. Because a dry treatment involves less time and labour than a wet treatment, the use of dust fungicides is preferable when large quantities of grain are treated.

The analysis of the complete data obtained from the 1932, 1933, and 1934 large-plot tests indicated the existence of significant differences in yield due to seed treatment. A detailed examination of individual treatments in each experiment was made. A summary of the three-years' results is presented in Table 10.

Table 10 shows that in 1932 Marquis wheat seed treated with the organic mercury compounds produced a crop which outyielded to a significant degree the crop from untreated seed. In that year an increase of 8 bushels per acre was obtained by disinfecting seed with Ceresan. None of the treatments gave significant yield differences in 1933. In 1934 the results at Winnipeg and Brunkild were negative. In that year the untreated seed of Mindum wheat yielded a better crop than did seed treated with Ceresan or copper carbonate.

From the results of the three-years' experiments it would seem that the effect of seed disinfection on yield varies in an unaccountable manner. The unusually dry conditions which prevailed in Manitoba during the early part of the growing seasons may be closely associated with the poor

TABLE 10.—EFFECT OF SEED TREATMENT ON THE YIELD OF WHEAT IN 1932, 1933 AND 1934. (AVERAGE RESULTS OF 1/200TH ACRE PLOTS IN A LATIN SQUARE).

Year	Variety	Ceresan	Semesan	New Imp. Ceresan	Copper carbonate	No. treatment	Standard error*
1932	Marquis	24.6	21.0	21.3	—	16.4	1.48
	Mindum	20.7	15.9	21.4	—	18.4	1.77
1933	Marquis	11.7	—	9.5	9.7	10.0	0.80
	Mindum	10.2	—	10.3	9.4	9.7	0.58
1934	Mindum (B)†	9.6	8.6	9.3	8.9	10.9	0.59
	Mindum (W)	14.5	12.9	13.1	11.9	14.7	0.52

*Difference between means required for significance = Standard error $\times 2\sqrt{2}$
†(B)—Brunkild field. (W)—Winnipeg field.

yield results obtained in 1933 and 1934. These results suggest that the efficiency of seed treatment in the control of root-rot diseases of wheat depends, to some degree at least, on the amount of moisture in the soil at the time of, and subsequent to seeding. In general, however, the field experiments indicate the value of seed disinfection with organic mercury preparations for the control of root-rot of wheat caused by *H. sativum* and *F. culmorum*, although further studies are necessary to determine under what conditions these treatments are most beneficial.

SUMMARY

In greenhouse experiments, seed treatment with Semesan and Ceresan, both in liquid and dust form, and with New Improved Ceresan and Uspulun in liquid form, prevented root rot and wilt caused by *Fusarium culmorum* in seedling plants of wheat, oats, and barley. In liquid form these fungicides were found to give the best results at a concentration of 5% and a time interval of 2 minutes for the steep. Semesan gave slightly better control of the disease than Ceresan and New Improved Ceresan, and, unlike them, caused little or no seed injury. Uspulun was the least effective of the four fungicides.

Copper carbonate as a steep and a dust, and nickel sulphide and iodine-infusorial earth as dusts, gave practically no control. Cultural studies indicated that copper carbonate was but slightly toxic to *F. culmorum* and *Helminthosporium sativum*.

Formaldehyde as a steep increased the intensity of the disease. The treatment appeared to have an adverse influence on the growth of the seedlings, and probably on that account rendered them more susceptible to fungal attack.

Field experiments made in 1932, 1933, and 1934 showed that the organic mercury-fungicides gave good control of root-rot caused by species of *Helminthosporium* and *Fusarium*, as indicated by the increased seedling emergence and the decreased disease rating in mature plants. Copper carbonate did not control the disease. Formaldehyde tested only in 1934, tended to increase the amount of disease, and markedly decreased the yield. As far as effectiveness in controlling the disease was concerned, the dust or the liquid treatments with any one of these compounds are of about equal value.

In 1932 all the organic mercury-compounds significantly increased the yield of Marquis wheat. Where Ceresan was used the yield was increased 8 bushels per acre. In 1933 and 1934 yields were not significantly increased.

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Résumé

Etude du traitement de la pourriture des racines des céréales causée par Fusarium Culmorum (W. G. Sm.) Sacc. et Helminthosporium Sativum P., K., et B. J. E. Machacek et F. J. Greaney, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

Dans les expériences conduites en serre, le traitement de la semence au moyen de Semesan et de Ceresan, sous forme liquide ou en poussière, et avec le nouveau Ceresan amélioré et l'Upsulun sous forme liquide, a empêché la pourriture de la racine et la brûlure causée par *Fusarium culmorum* dans les plantules de blé, d'avoine et d'orge. Sous forme liquide ces fongicides ont été les plus satisfaisants en concentration de 5 pour cent et à intervalle de 2 minutes pour la macération. Le Semesan a paru avoir un peu plus d'effet que le Ceresan et le nouveau Ceresan amélioré, et il s'est montré supérieur à ces derniers en ce sens qu'il n'abîmait point la semence. L'Upsulun est celui des quatre fongicides qui a été le moins efficace. Le carbonate de cuivre employé en bain et en poussière, le sulfure de nickel et la terre infusoriale-iodée employée en poussière, n'ont eu presque pas d'effet. Les essais de culture ont indiqué que le carbonate de cuivre n'est que légèrement toxique pour *F. culmorum* et *Helminthosporium sativum*. La formaldéhyde employée en bain a augmenté l'intensité de la maladie. Le traitement paraît avoir exercé un effet retardataire sur la végétation des plantules, et les a probablement, à cause de cela, rendues plus sensibles à l'attaque des champignons. Les expériences conduites dans le champ en 1932, 1933 et 1934 ont montré que les fongicides organiques de mercure ont donné un bon contrôle de la pourriture de la racine causée par les espèces *Helminthosporium* et *Fusarium*, indiqué par le nombre plus élevé de plantules et par la diminution de la fréquence de la maladie chez les plantes adultes. Le carbonate de cuivre n'a pas enrayé la maladie. La formaldéhyde qui n'a été essayée qu'en 1934 avait une tendance à augmenter la quantité de maladie et elle a fortement abaissé le rendement. En ce qui concerne l'efficacité au point de vue de l'enrayement de la maladie, la poussière ou le traitement liquide avec l'un ou l'autre de ces composés ont à peu près une valeur égale. En 1932 tous les composés organiques de mercure ont accru dans des proportions notables le rendement du blé Marquis. Lorsque le Ceresan était employé, le rendement s'est accru de 8 boisseaux à l'acre. L'augmentation de rendement a été peu sensible en 1933 et 1934.

UNDERDRAINAGE EXTENSION WORK IN ONTARIO[1]

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In 1905 Professor J. B. Reynolds was head of what was then known as the Department of Physics and English at the Ontario Agricultural College. Realizing the necessity of some assistance that would enable farmers to meet their drainage problems, he made a recommendation early that year to the Minister of Agriculture. He proposed that the Department take levels and prepare plans giving all specifications for drainage installation, the farmer being responsible for necessary travelling expenses. This was kindly received by the Minister of Agriculture. At the Canadian National Exhibition Professor Reynolds was asked to address the farmers on the subject of "Farm Drainage", when he announced for the first time to the farmers the assistance his department was prepared to give in this direction. Following this announcement, correspondence was received from seven different centres in Ontario, namely, Grimsby, Exeter, Wiarton, Mt. Forest, Whitby, Fergus and Lancaster.

In 1906 the aforementioned department was divided, Professor Reynolds taking charge of the English Department and Professor Day, who had been assistant to Professor Reynolds for several years, the Physics Department. During that season, however, Professor Reynolds fulfilled his obligations with regard to correspondence he had received in connection with drainage surveys and made twelve personal surveys. During the same summer Professor Day made fourteen surveys.

During the early part of 1907 a number of articles were written for the Farmers Advocate, and announcements with regard to drainage surveys made in a number of the weekly publications, with the result that during the spring 126 applications were received. Of these 70 were attended to, 34 being done by Mr. Thon, Professor Day's assistant, 25 by Professor Day and 11 by Mr. Wolverton, whose services were obtained for one month.

During 1908 three extra men were employed in connection with drainage work; 166 applications were received and 100 surveys made. During this year the department became interested in the operation of the first ditching machine known to be in the country, owned and operated by Mr. Jacob Schihl of Woodslee, Essex county. Following this demonstration, Professor Day made a trip to the Buckeye factory, Findlay, Ohio, and was quite impressed with the possibilities of the machine they were making. In 1909, 302 applications were received for this work. During the same year two other ditching machines were imported.

Interest has continued in drainage work throughout the intervening years. Up until the spring of 1918 the survey work was carried on by students during the summer time. It was found that this method had some objections, namely, the yearly necessity of breaking in new men and very often having them for one year only, releasing them when they were really getting into shape to handle the difficult problems that turned up

[1] Paper read before the Agricultural Engineering Group of the C.S.T.A. at Macdonald College, P.Q., June 26 and 27, 1934.

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on some of the jobs. Secondly, the lack of help during October and November when drainage work is usually very active and the students had returned to their classes. It was decided in 1918 to make permanent appointments in strategic points within the province so the efficiency of the work could be raised. This method is still being used and is proving satisfactory. At times it has been necessary to appoint a couple of extra men during the summer time to help with the rush work.

Up until the time of the permanent appointments in 1918 the old method of operation has been in vogue, that is, the men received a certain salary and collected their expenses from the parties for whom they worked. With the permanent appointments the men received salaries and also expenses and for three years no charge was made for the work to the farmers. This arrangement was unsatisfactory because of the fact that it did not put any value on the work and a number of the farmers requested surveys of their farms in order to get maps without having in mind the installation of any drains whatsoever. It was decided that it would be better to make a small charge to overcome these difficulties.

At the present time there are four permanent appointments for this work at Hamilton, Chatham, Stratford and Kemptville. The men now instead of travel ing on trains and busses as before drive their own cars for which mileage is paid. This makes it possible for them to carry all the necessary equipment, changes of clothing, rubber boots, stakes, instruments and other equipment which they were unable to carry before.

Even during the last few years of the so-called depression, interest in drainage work has been very well maintained. It dropped a little in 1932, but during 1933 lower tile prices and lower costs of machine work gave an added stimulus to the work and the season was an exceptionally busy one. In that year 509 farmers were given assistance with their drainage problems in one way and another; 217 actual surveys were made, and of these the work on 185 had been started or completed up to last fall. This is very satisfactory as it represents 84% of the work surveyed.

Inspection Work

It is very difficult to make any accurate estimate of the amount of drainage work that has been done in Ontario during one any season as the surveying done by the department does not represent the work done. A number of farmers do work themselves without having a survey. It is further difficult to get all the tile yards to give a report on the tile sold each year, largely perhaps because they do not keep very accurate records or perhaps, which is more important, is the fact that they do not consider it worth while to send in a report. There are in the neighborhood of 100 tile manufacturing plants and about 180 ditching machines in the Province. These, of course, have not all been actively enaged during the last few years in drainage work, but a good many of them, particularly those in Western Ontario and the Niagara district, have been kept in pretty steady operation.

Demonstrations

During the earlier years of the department's work when surveys were made, a surveying demonstration was given at the time the survey was made. Farmers of the district would be invited to attend and benefits and ways and means of doing drainage work were discussed. In 1912 the

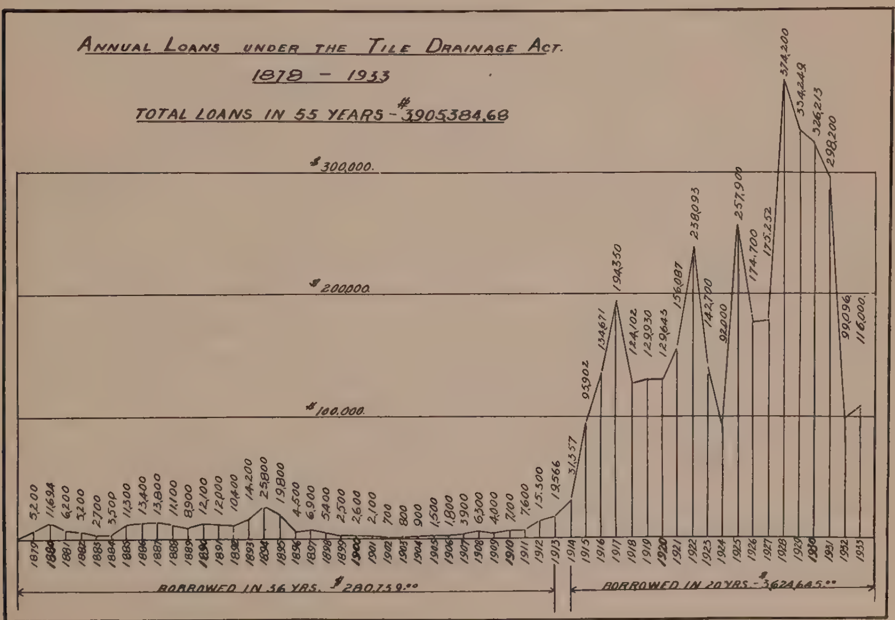
department purchased a machine of their own and during the next four years established drainage demonstration plots in various sections of the province. In all, 29 plots were put in. This gave the farmers a chance to see the ditching machine in operation. It also served to show what drainage would do on wet land and furthermore it gave the members of the department a chance to hold demonstrations and explain tile drainage to the interested farmers.

During the years 1925, '26, '27, '28 and '29 nine more plots were installed in Eastern Ontario, where only a few had been put in during the previous years. These have served to promote a good deal of activity in this section of the province.

The Tile Drainage Act

The Tile Drainage Act has been one of the most satisfactory pieces of legislation that has ever been passed by the provincial authorities. It was on the statute books long before the department took any interest in assisting the farmers with their drainage problems. Briefly, it makes possible the installation of tile without any serious financial outlay on the part of the farmer himself. The act has, of course, been amended from time to time as was necessary under changing conditions.

At the present time the government has set apart three million dollars of the Consolidated Revenue Funds of the Province to be used by the municipalities for drainage work. Each municipality can borrow as high as $200,000, and even $300,000 if the total assessment of the municipality is three million dollars or over. It is necessary for the municipality to pass a bylaw establishing a credit with the Provincial Government for whatever money they think their township might be able to use over a period of years. When this bylaw has been passed and the necessary



papers made out by the municipality and filed with the government they are in a position to accept applications from the farmers for loans for their drainage work. Usually, however, the bylaws are not considered until some of the farmers in the municipality become interested in drainage work and make an application for a loan.

The individual farmer can borrow 75% of the cost of his drainage work up to $2,000 per 100 acres or fraction thereof. He gets this over either a 10 or 20-year period at 5% interest and repays it annually in his taxes at the rate of $12.95 or $8.03 for every $100 borrowed, depending on whether he borrowed it under the 10- or 20-year scheme.

Up to the present time some eighty municipalities in the province have passed the bylaw and are making loans to their ratepayers for this work. This loan, I may say, has prior rights on a man's property and comes ahead of a first mortgage. Consequently the mortgagee must give his consent before a loan can be made. The municipality appoints an inspector who makes a report on the work that has been completed showing the total cost of the work, and 75% of this is calculated in preparing the necessary debenture for sale to the Provincial government. It is possible for a man doing drainage work to work out pretty well the 25% which he is required to furnish by drawing and spreading tile, backfilling the trenches, board of men, etc., so that it is possible for him to do drainage work without making any large cash outlay.

Provision is made for him to pay the loan off at any one time if he wishes, but he either makes his annual payments or retires the entire loan.

A STUDY OF THE BEHAVIOUR OF THE WATER TABLE IN UNDERDRAINED AND SURFACE-DRAINED RIVER VALLEY SOILS IN QUEBEC (A PROGRESS REPORT)[1]

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The chief agricultural producing areas of the province of Quebec lie in the valleys of the St. Lawrence, Ottawa, Gatineau, Chateauguay, Yamaska, St. Maurice, Saguenay and other smaller rivers.

Since the soils of these areas are largely of sedimentary origin they and their sub-soils consist mainly of various types of clayey formations. Because of their elevation, they are subjected not only to normal precipitation but also to the run-off from adjacent slopes, and, due to their level topography, satisfactory surface drainage is often difficult if not impossible.

In the past, before the day of the automobile, these areas enjoyed prosperity and found a good market in the larger cities, and to some extent in England, for their chief crop—timothy hay. In the course of time, however, as the taxi and truck replaced the "cabby" and horse drawn lorries, the market for timothy hay narrowed very materially. Accordingly it became necessary for our hay producers to adopt rotational farming, and in many districts this change is at present in progress.

Whether it was a matter of chance or design that timothy became the main crop of these areas, the early farmers of the St. Lawrence and other river valleys were extremely fortunate in the possession of a plant so splendidly adapted to the poor drainage conditions which are almost universal in these lands. Timothy seems to grow abundantly wherever there is a layer of 3 or 4 inches of good soil, and, so long as the saturation level was not nearer the surface than this during the growing season, a good crop was assured. With the introduction of rotational farming, with its deeper feeders and more frequent cultivations, these meagre depths of water-free soil proved entirely inadequate. While some of the gramineous crops will do fairly well, in favourable years, on land of indifferent drainage, clovers and alfalfas cannot be grown successfully under these conditions. The importance of these crops to successful diversified farming is universally recognized. The roots of clover and alfalfa penetrate to considerable depths in the sub-soil, but if the sub-soil is water-filled this root development is curtailed, with obvious results.

Figure 2 records the results of recent research on this phase of the subject and shows how root development is seriously hampered by free water in the soil.

The need for more abundant drainage has been apparent to the Department of Agriculture of the Province of Quebec for some years. About 1910, ditching machines were purchased by the government of the province for the purpose of demonstrating and assisting in the installation of farm drains. Drainage systems were installed on various farms in different

[1] Paper read before the Agricultural Engineering Group of the C.S.T.A. at Macdonald College, P.Q., June 26 and 27, 1934. Contribution from the Faculty of Agriculture of McGill University, Macdonald College, P.Q., Canada, Journal Series No. 61.

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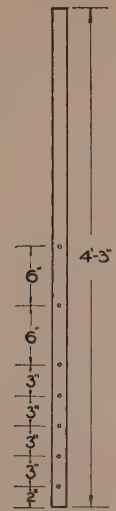

FIG. 1-GAUGE PIPE SHOWING SPACING OF 3/16" PERFORATIONS

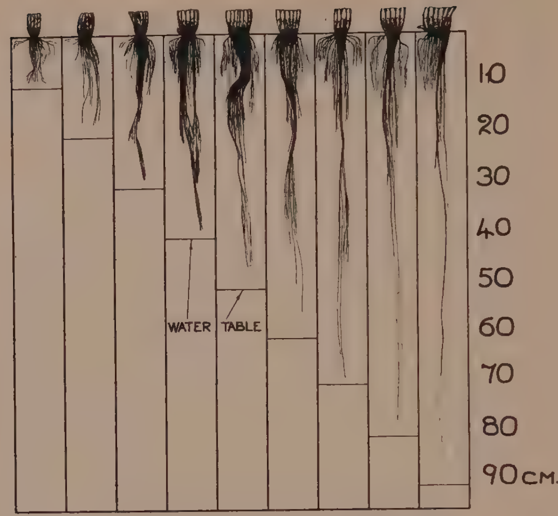

FIG. 2-SHOWING HOW ROOT DEVELOPMENT IS CURTAILED BY SATURATION LEVEL IN SOIL
(COURTESY OF IMPERIAL BUREAU OF SOIL SCIENCE)

parts of the province to demonstrate to these communities the value of this form of land improvement. This work, of course, was not very extensive, having been done almost without expense to the farmer. Also, in 1920, there was placed on the statute books the "Drainage Act", which gives to municipalities the right to borrow money to be advanced to farmers for drainage purposes. Any farmer owning land which justifies the expenditure for a drainage system may call on his municipality to raise funds in this way for his purpose, but to the writer's knowledge the "Drainage Act" has never been put into use.

However, before this government-aided extension work could bear fruit, there came serious intervention in the form of the Great War, bringing with it high prices, scarcity of labour and consequent cessation of all drainage efforts. Since then the generally unsettled condition of agriculture, and more recently, the depression have prevented a resumption of interest in this form of land improvement.

With a view to the future needs of Quebec farmers, and after some years of observations of the performance of drains in various fields, it was felt that a study of underdrainage performance in the province was necessary. It was believed that possibly our soils and subsoils may contain factors not common to the experiences with tile drainage in Ontario and elsewhere. After some consideration, therefore, it was decided to establish a series of plots where influence of underdrains on the water table in our soils could be observed and recorded.

Experimental Work

Primarily this project is one of a study of the behaviour of the water table in drained and undrained adjacent fields. It is the hope that the following objectives can be reached:

1. To determine the extent to which drains, now installed, are effective in controlling the water table.

2. To determine optimum depth and spacing of tile drains.

3. To determine the physical characteristics of the soils and subsoils of our typical, heavy, river-valley lands.

4. To determine the economic value of underdrainage in our soils.

Four observation plots were located as follows:

1. Ste. Rosalie in Ste. Hyacinthe County.
2. Howick in Chateauguay County.
3. Ormstown in Chateauguay County.
4. Hudson Hts. in Vaudreuil County.

In each of these plots tile drains had been in operation for some years,

TABLE 1.—RESULTS OF MECHANICAL ANALYSIS OF SOILS

Location	Sample	Sand %	Silt %	Clay %	Loss on ignition %	Difference %
Hudson Heights	Surface	17.57	33.75	40.5	6.18	2.00
	Subsurface	8.68	31.00	51.0	6.65	2.67
	Subsoil	3.8	28.25	60.5	5.84	1.61
Ormstown	Surface	8.5	24.2	56.1	8.7	2.5
	Subsurface	10.5	16.6	64.2	7.87	0.83
	Subsoil	4.1	12.1	73.02	8.5	2.28
Howick	Surface	11.4	45.5	30.0	9.6	3.5
	Subsurface	5.2	37.0	49.0	6.58	2.22
	Subsoil	4.1	27.75	61.25	5.25	1.65
Ste. Rosalie	Surface	13.5	22.0	52.25	10.1	2.15
	Subsurface	2.6	4.25	84.0	6.77	2.38
	Subsoil	1.5	4.0	85.5	7.2	1.8

and adjacent to each there is available undrained land to serve as check areas. These plots seem to be typical of our river valley soils.

The equipment used was similar to that used by Schlick in his experiments and consisted of gauge pipes (Figure 1), lines of which were installed at right angles, between two lines of tiles, as shown in the accompanying graphs. The gauge pipes were made of $\frac{3}{4}''$ galvanized pipe 4′ 3″ long, with 3/16″ holes drilled through both sides and placed as shown on the diagram of the pipe.

The gauge pipes were placed at varying distances apart, depending upon the distance between the tile lines. Pipes were placed in check plots also, sufficiently far removed from the drained area to make available a water table not affected by the tile. These pipes were set in holes bored with a small soil auger and were placed so that about $2\frac{1}{2}$–3″ projected above the ground surface. After the pipes were set and the soil filled in around them, the elevations of the tops of the pipes were taken with a level and recorded.

The elevation of the water table was determined from measurements taken in the gauge pipes. The owners or operators of the farms on which the plots were located co-operated with the Department and at frequent

intervals read and recorded the distance from the top of each pipe to the level of the water inside it. A 3/8″ square graduated rod was provided for this purpose. From these readings and the predetermined elevations of the pipes, by subtraction, the elevation of the water table was calculated.

Soil Analysis

In co-operation with the Physics Department of Macdonald College mechanical analyses of the soils on each plot were made. The results of these tests are shown in Table 1.

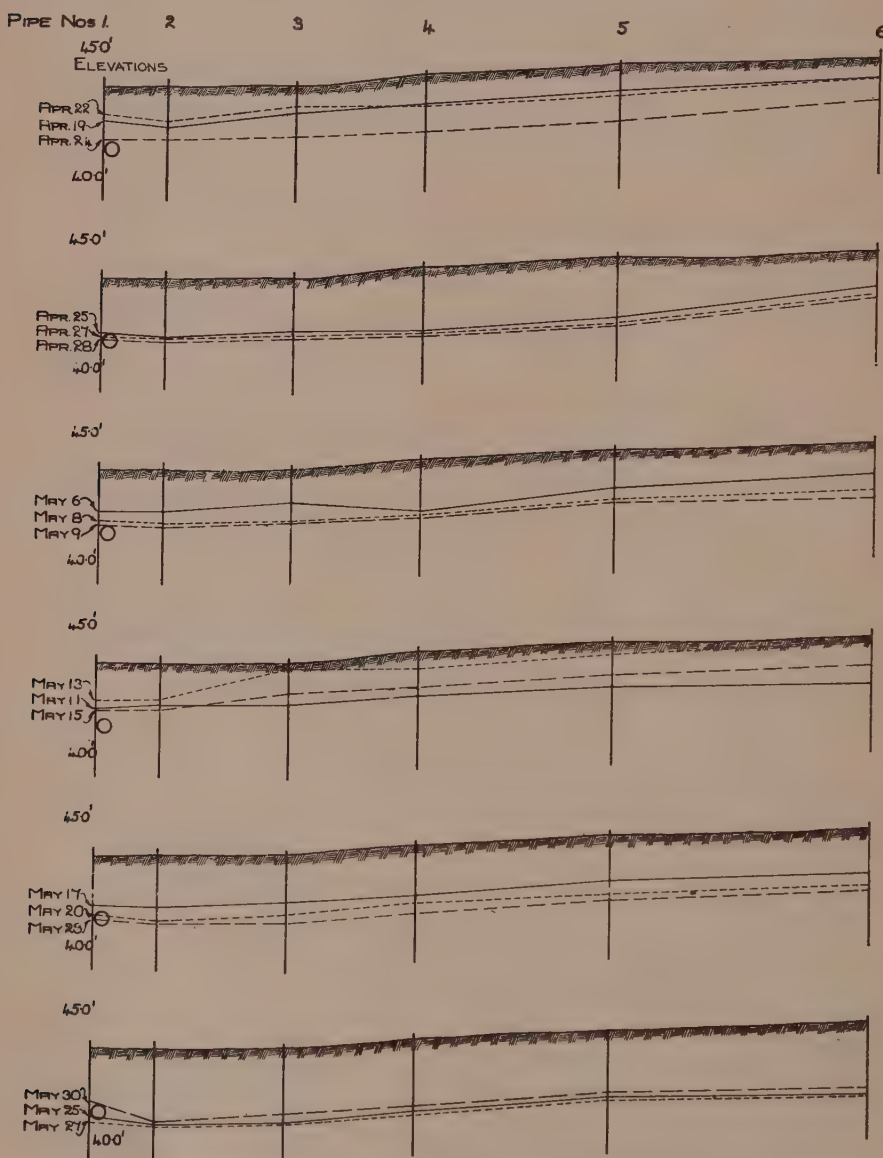

Fig. 3
Ground Water Fluctuation Diagrams.
Hudson Heights, Que.

It will be noted that in each case the subsurface and subsoils are heavy clays.

Results

Little discussion need be given to results, as the accompanying graphs, typical of drainage conditions during periods when the saturation level is fairly high, indicate the elevations of the water table in drained and undrained plots for the given dates.

Hudson Heights Plot

It will be noted from the graph, Figure 3, that one line of tile only is installed on this plot, and it is located in the lowest part of the field. Ordinarily it might be expected that the water table would be nearer the surface in the lower land. The graphs show, however, that the water

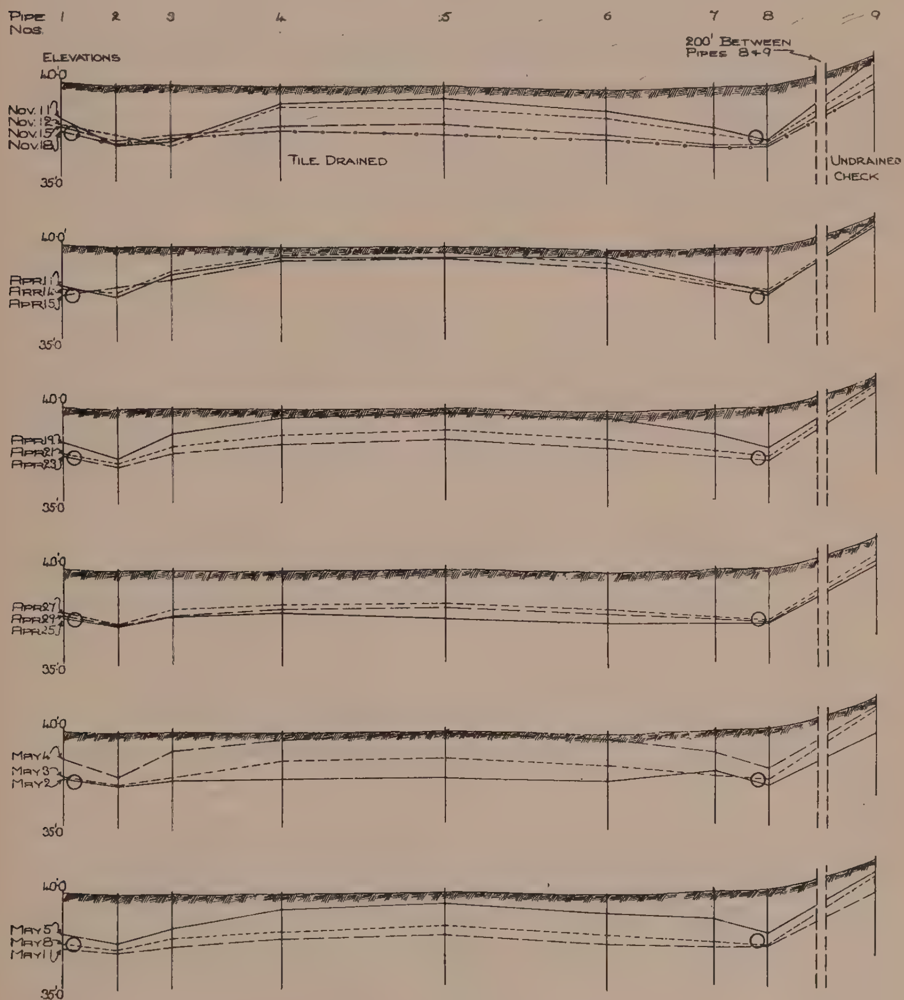

FIG. 4
GROUND WATER FLUCTUATION DIAGRAMS.
ORMSTOWN, QUE.
1932-33

table is at its lowest near the tile line and rises more or less regularly to the last gauge pipe.

Ormstown Plot

On this plot, about twenty years ago, a tile drainage system was installed with drains at 65-foot intervals, and one entire field was drained. Gauge pipes were located between a pair of these drains, and two pipes were placed as checks in an adjoining undrained field 200 feet from the fence separating the two fields (See Figure 4.).

Two points of interest are brought out by this plot:

1. The extreme difference between the height of the water table in the drained and undrained fields.
2. The regular curve of the water table between the drains.

It is interesting to note the behaviour of the water table in this plot between the tile lines after heavy rains. While the saturation level rises almost to the surface during heavy rains, it goes down very quickly. The action of the drains in this field seems to be sufficiently prompt and dependable to exercise a very beneficial influence on crop yields.

Howick Plot

The gauge pipes in this plot were located in a field which was a considerable distance from the farmstead, and this, together with the fact that the owner of the farm was rather short of help at the time, resulted in few readings being taken.

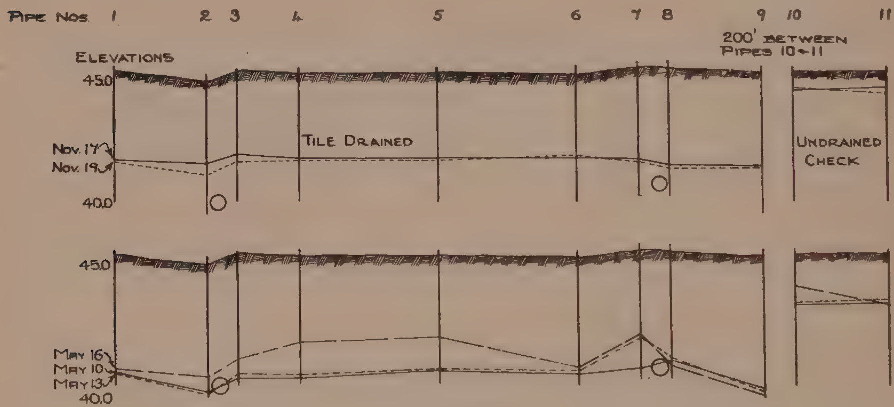

Fig. 5
Ground Water Fluctuation Diagrams
Howick, Que.

What readings were taken showed that the drains exercised a very definite influence on the water table during periods of excess soil moisture (Figure 5). An indication of the beneficial effects of underdrainage on this soil was brought to light on May 5, 1933, during a visit to the plot by the writer. On this date, the soil in the undrained check plot was saturated to within three inches of the surface, while in the tile-drained field the water table midway between the drains was 19″ below the surface, and 5 feet from the drains it was 30″ below the surface. Water stood on the surface in almost all dead-furrows and depressions in the check plot and the soil could only be described as very wet, while the owner was

preparing for spring tillage operations which could be begun in a few days on the drained land.

It should be mentioned also, that the land in the check plot was exceedingly well located for surface drainage, the gauge pipes in the check plot being located not over 200 feet from an open ditch about 7 feet deep located between the drained and undrained fields.

The water table in the drained field does not quite obey the general rule—that is, to form an arc towards the surface between the drains. Perhaps this can be explained by the fact that the drains on this farm have been in the ground for nearly 30 years and thus have had ample time to influence the structure of the soil between the drains.

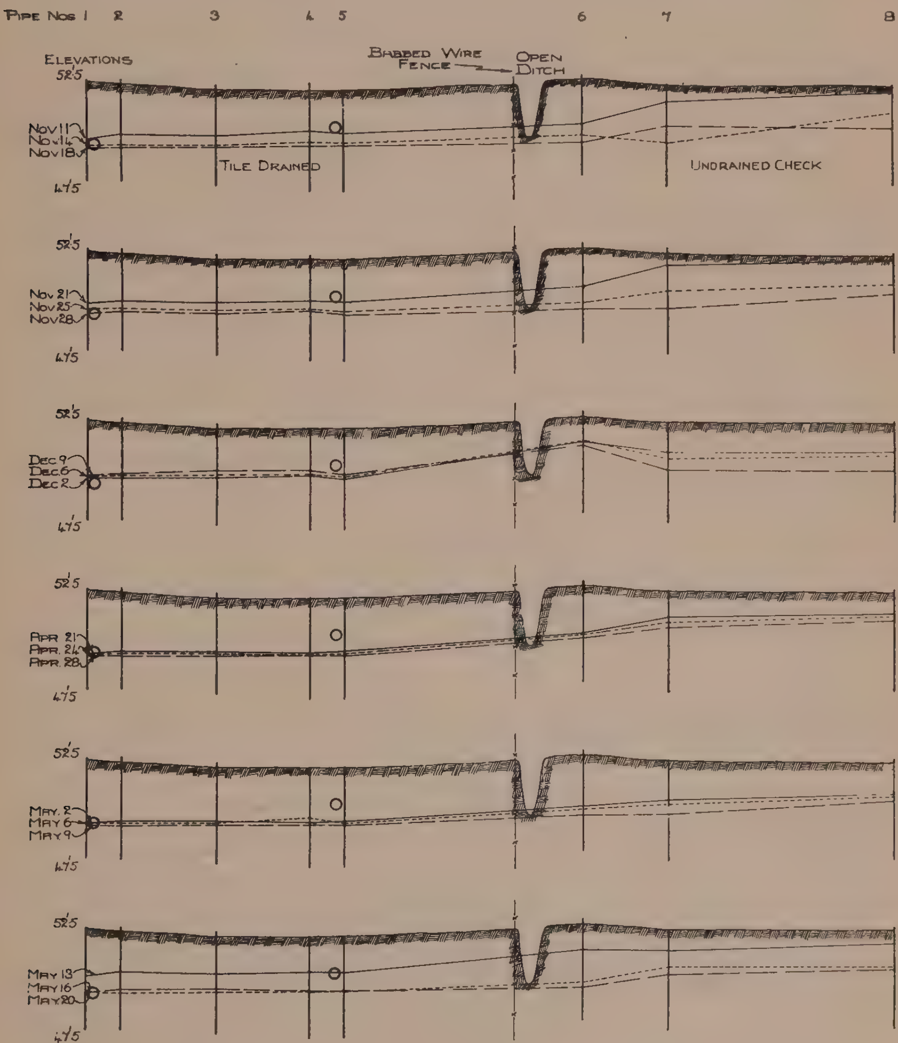

FIG. 6
GROUND WATER FLUCTUATION DIAGRAMS
FOR THE FARM OF THE COOPÉRATIVE FÉDÉRÉE,
ST. ROSALIE, QUE.
1932–1933.

Ste. Rosalie Plot

When the gauge pipes were installed on this plot it was felt that here, if anywhere, the ability of tile drains to lower the water table would be tested. The soil was very plastic, being 89.5% clay, and the writer felt that movement of water in the soil would be very slow, if indeed the water could find its way to the tile at all. The water table in the check plot was influenced to some extent by the presence of an open ditch. This ditch was about 3 feet deep, and, since the gauge pipes were placed 8′, 25′ and 65′ respectively from it, it is reasonable to assume that the water table was affected by the presence of the ditch.

The graphs of early tests show a marked difference of elevation of water table in favour of the drained land (See Figure 6). The results in the fall of 1933 and spring 1934 do not show such a marked difference. During our visit to this plot in the fall of 1933, we found that the outlet ditch had been allowed to fill in, and there was considerable vegetation in the ditch. We believe that this hampered the discharge of the tiles. This belief was partially substantiated when, during a visit to the plot in the spring of 1934, it was found necessary to take up and replace several broken tiles. While the winter of 1933-34 was rather severe, experience has shown that frost injury to tile is caused only when water has been allowed to freeze in them, and we believe this to be the root of the trouble in this particular case.

In spite of the extremely heavy clay subsoil of this plot the drains exert a very beneficial influence on the water table, particularly during the saturation period of the year, from November to May.

SUMMARY

1. On land tested to date in these plots, tile drains have shown, definitely, their ability to lower the water table.

2. From the writer's observations and the farm owners' records (usually observation) crops grown on drained land are superior in quality and yield to those grown on undrained land.

3. Soils on which the plots were located showed medium to heavy clay subsoils.

4. Farm owners estimated that it was possible to get on the drained land about ten days earlier in the spring than on the undrained land.

Résumé

Une étude du comportement du niveau d'eau dans les sols égouttés au moyen du drainage et de l'égouttement de surface. R. Millinchamp, Collège de Macdonald, P.Q. D'une vallée de rivière dans le Québec.

Sur les parcelles où ces essais ont été conduits, les tuyaux de drainage ont montré très clairement qu'ils peuvent abaisser le niveau de l'eau. D'après les observations de l'auteur et les notes des propriétaires de ferme (généralement des observations) les récoltes cultivées sur terre drainée sont supérieures en qualité et en rendement à celles cultivées sur terre non-drainée. Les sols sur lesquels des parcelles étaient établies avaient des sous-sols d'argile lourds ou mi-lourds. Les propriétaires de ferme estimaient que l'on pouvait travailler la terre drainée environ dix jours plus tôt au printemps que la terre non drainée.

OAT SEEDLING DISEASES IN ONTARIO

I. THE OAT NEMATODE *HETERODERA SCHACHTII* SCHM.

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INTRODUCTION

A cereal root parasite of major importance, the oat strain of the nematode *Heterodera schachtii* Schm.,[2] has made its appearance in Ontario. This species which comprises several biologic races, has been known for many years in Europe where it occurs upon a variety of crop plants. The sugar beet race has for some time been present in the United States, and has been reported once (*1*) in Canada, but this is the first record of the occurrence of the oat race in North America.

During the summer of 1932, the Ontario Research Foundation was asked by farmers in South Simcoe County to investigate the cause of the repeated failure of their spring grain crops. Since the region has been settled for a comparatively long time and has always been more or less specialized to cereal farming, it was suspected that the exhaustion of soil nutrients might be responsible. Extensive soil tests, however, did not reveal anything upon which the blame might be placed and attention was then directed toward the investigation of root-inhabiting parasites.

The nematodes were first discovered in July, 1933, upon the roots of oat plants grown in oat-sick soil in the green house. A partial survey including fifteen fields in which the crops were very poor or patchy showed that nematodes were consistently found upon the roots of sick plants. It is not known how long this parasite has been present in the area, but farmers report that failures of spring grain crops have occurred for at least ten years, and it is now impossible to trace the original infestation.

LITERATURE

The literature dealing with this parasite has been well surveyed recently by Goodey (*6*) and a complete bibliography on the genus *Heterodera* has been issued by the Imperial Bureau of Agricultural Parasitology (*9*). *Heterodera schachtii* was first reported on oats and barley by Kühn (*10*) in 1874, and Voight (*17*) in 1892 found that the oat and beet strains with which he worked were apparently specialized upon their respective hosts. Since that time various investigators have shown that the oat race is capable of attacking practically all the cereal crops, though Nilsson-Ehle (*11*) has indicated that some strains of barley are resistant. The oat race has been described in Germany, Holland, Norway, Sweden and Denmark. According to Davidson (*2*), *Heterodera schachtii* has probably been present since 1906 on cereals in South Australia, and Hickenbotham (*8*) correlated the presence of nematodes with "no growth" patches in barley and oats. The most recent work on this pest is given in the valuable account by Goffart (*5*) from Schleswig-Holstein.

[1] Research Fellows in Agriculture. During part of the period in which this investigation was under way, Dr. Putnam was Assistant in the Department of Botany, University of Toronto.

[2] We are indebted to Dr. Gerald Thorne, Associate Nematologist of the U.S.D.A., for confirmation of the identification of this parasite.

A nematode infesting the roots of wheat in Saskatchewan was reported by Russell (*12*), but it has been described by Thorne (*15*) as a new species, *Heterodera punctata* Thorne.

Brown (*1*) reported the presence of the sugar beet race in a single field in Western Ontario, but it has not since been found anywhere else in Canada.

SYMPTOMS

In the outbreak under consideration, total as well as partial crop failures have been noted in the case of both oats and barley, but as a rule the oat crop suffered much more heavily. In fields of mixed grain it has often been observed that the oats have been a complete failure and that the grain harvested was nearly all barley. In view of the fact that the disease is much more noticeable on oats, most of the discussion on symptoms will be based upon the appearance of diseased oat plants.

It is possible to distinguish the diseased plants about two weeks after they appear above ground. They do not appear to be growing at a normal rate and the crop is often spoken of as "standing still". In addition, the plants have a "staring" appearance; that is, the leaves, of which there are usually two at this stage, stand stiffly erect with somewhat inrolled margins. The most striking symptom and the one which has locally given to the disease the name of "red leaf", is the brick red tinge which rapidly spreads over a patch or a field when the plants are about three weeks old. The discolouration begins at the tip of the first leaf, the whole of which then gradually becomes brick red and eventually withers. In many cases the second leaf also becomes discoloured, and sometimes even the upper portion of the third leaf.

While, in the main, the colour of the leaves on diseased seedlings may be described as brick red, there is some evidence that the supply of available nutrients may influence the appearance and severity of the symptoms. Increasing the available phosphorus in the soil by the application of acid phosphate imparts a distinct orange shade to the leaves; where muriate

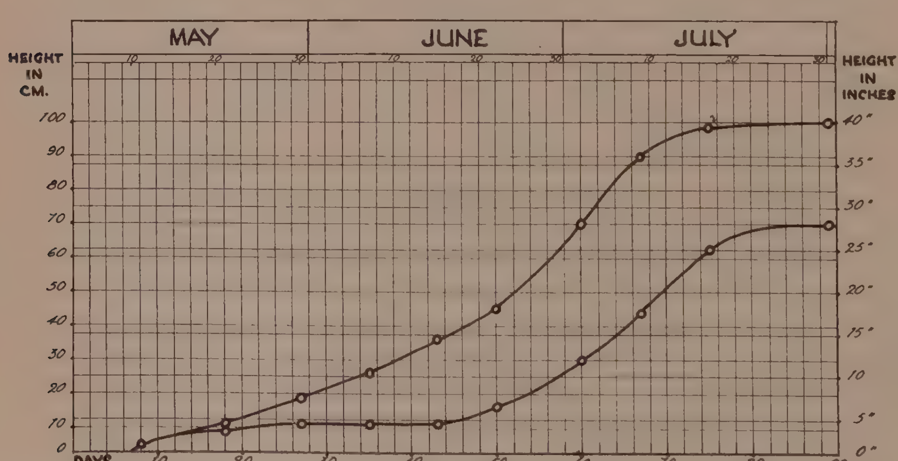

FIGURE 1.—Chart showing comparative average heights of healthy and diseased oat plants throughout the growing season of 1934.

of potash was applied alone, a purplish shade was evident; and with a moderate application of ammonium sulphate the discolouration was inclined to be yellowish. The greatest effect was obtained when a combination of ammonium sulphate and superphosphate was applied. The "red leaf" condition was much intensified and rapidly involved all the leaves on the plants which were very much stunted, and in fact, many of them were killed outright.

The "red leaf" stage usually lasts about a week or ten days, after which the plants put out new green leaves, and the discoloured ones wither and drop. The growth of the plant, however, has received a check from which it never recovers. The chart in Figure 1 shows that diseased plants are always shorter and mature later than healthy ones. In dry years badly diseased plants never come into head at all, while in years of moderate rainfall such as 1934, a fair crop may be harvested even in spite of a moderate infestation.

Tillering, while never very abundant under ordinary field conditions, is practically non-existant in diseased plants. The panicles seldom have more than half the ordinary number of spikelets and the grain is poorly filled, many florets being empty. The culms are much slimmer and weaker in diseased plants. Except in special cases, however, very few plants actually succumb, though one wonders how they manage to exist. The typical mature plant in a badly infested patch (Figure 2) is about one foot or fifteen inches in height, bearing a head of from one to five unfilled grains.

The general appearance of infested fields deserves some mention. Only a few fields are uniformly badly infested, although there were some in which it was impossible to find a healthy plant, even in 1934. Infested fields usually have a patchy appearance (Figure 3) which becomes greatly intensified as the season advances because of the abundant growth of weeds, particularly of sow

FIGURE 2.—Mature oat plants in a badly infested patch (1933). This field contained only this one diseased patch in both 1933 and 1934.

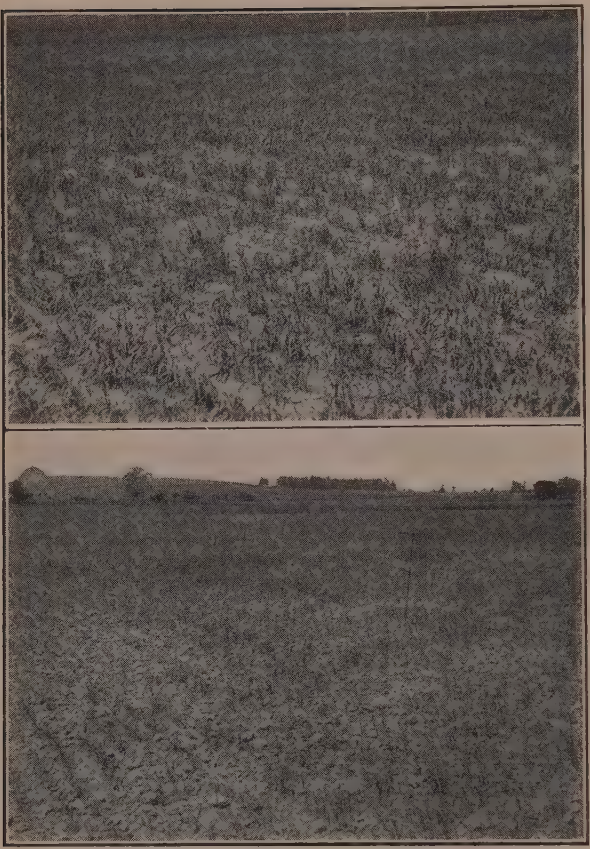

FIGURE 3.—The appearance af a typically diseased field in June, 1933.

thistle. Sometimes a field may be found in which there is only one patch, while in others there may be a great many. Patches may vary in size from a few feet to several rods in diameter. Sometimes they are elliptical or oblong with their long axes parallel to the prevailing direction of cultivation. It is interesting to note that Hickenbotham (*8*) makes the same observation with respect to the "no-growth patches" associated with the presence of this parasite in Australia.

It has been repeatedly observed, both in 1933 and 1934, that in diseased patches, one drill row may be much poorer than the others and that such poor drill rows apparently extend farther into the better areas surrounding the patches. Examination of adjoining rows revealed that in the case of the better plants the seed had been sown more deeply, while in the poorer drill row it had been covered with only an inch or so of soil. In one badly infested field it was observed that the oat plants were noticeably taller in the wheel marks of the tractor which had been used in cultivation. The result of soil compression in this case was probably the same as that of deep sowing, namely, to make available a more dependable supply of water to the struggling plant.

Striking as may be the appearance of the aerial parts of diseased plants, the difference between healthy and diseased root systems is even more marked and more specific, and is quite evident in carefully washed seedlings long before any difference is discernible in the appearance of the leaves.

The examination of seedling plants some ten or twelve days after they appear through the soil does not disclose any great difference in the aerial parts, but the difference in the roots may be very great. The seminal root system of a diseased plant is usually only a fraction of the length of that of healthy plants of the same age. Whereas the healthy roots were long,

PLATE I.—1. A comparision of healthy and diseased oat root systems in the early stage of growth. ($\times\frac{2}{3}$). 2. Diseased oat plants twenty-four days from date of sowing. ($\times\frac{1}{2}$). 3. Diseased oat plants six weeks from date of sowing. ($\times\frac{1}{2}$). 4. A single root from a diseased plant, showing the excessive branching. ($\times 12$).

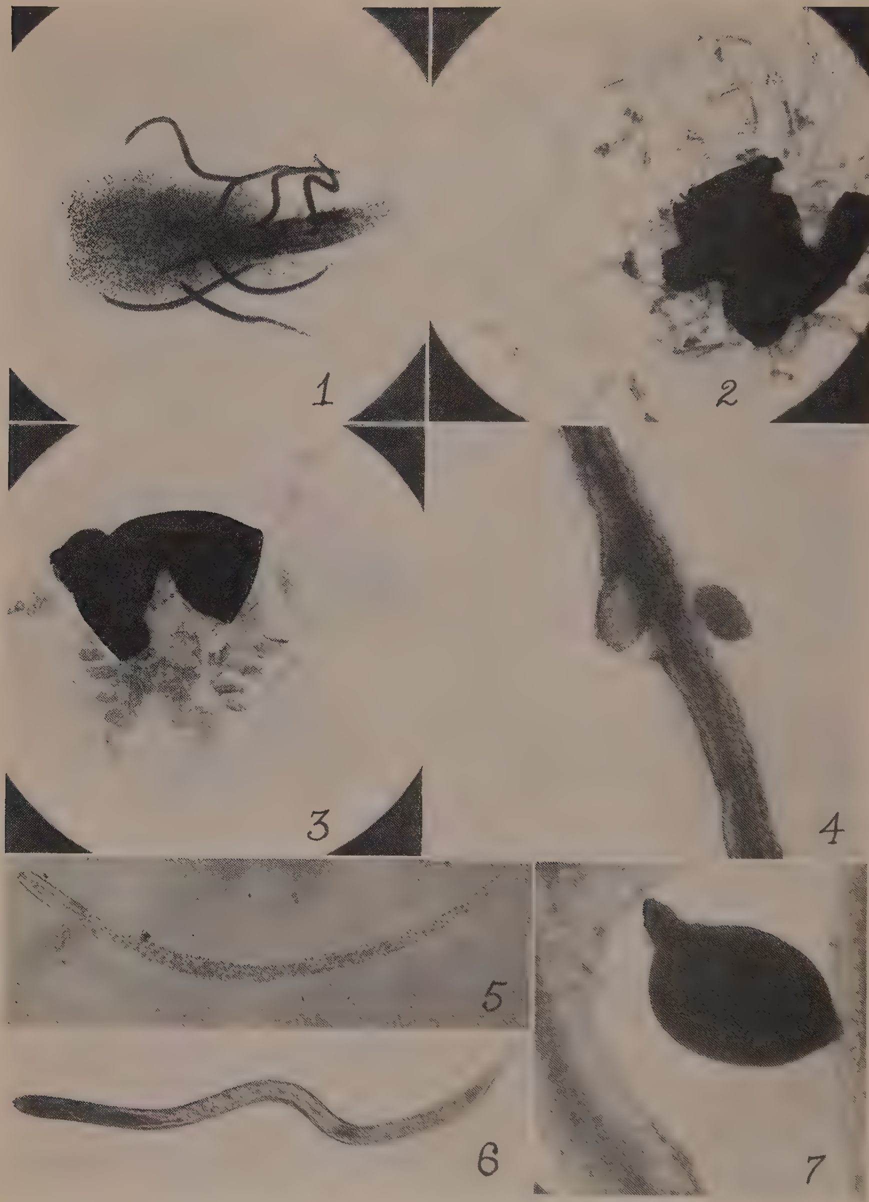

PLATE II.—1. An oat root tip infested with nematode larvae. (×37). 2. First stage larvae obtained by crushing a brown cyst. (×37). 3. A brown cyst containing eggs, each with a coiled larva inside. (×37). 4. Mature female nematodes (white cysts) attached to an oat root. (×21). 5. A first stage larva, just released from the brown cyst. (×150). 6. Nematode larva obtained by dissecting out an infested root tip. (×150) 7. Mature female nematode detached from root. (×47).

slim, white and almost unbranched, the diseased roots were short, crooked, thickened, discoloured and beset with short stubby laterals (Plate I, 1). The excessive branching imparts the matted appearance that is always shown by investigators as a typical symptom of the disease. The texture of the diseased roots is characteristically crisp, and the colour even after washing, is a dirty yellow or yellowish brown. It is usual to find that the nodal or crown roots appear much more quickly than they do on healthy plants, thus keeping the root development close to the surface.

A week or so later, when the "red leaf" stage was at its peak, it was found that an abundance of short lateral rootlets had been put out (Plate I, 2), giving the seminal roots a thickened, matted appearance, though very little increase in length had taken place. The nodal roots had grown somewhat in length but were also becoming thickened at the tips and studded with short lateral branches. It was found that for a period of about three weeks the diseased plant was not able to increase effectively its area of occupation in the soil and in consequence of this limited capacity for absorption the aerial development was restricted to a small fraction of that of a healthy plant.

At various times during the period of the most marked symptom expression, that is, from about three to six weeks after planting, collections of both healthy and diseased plants were made, care being taken to preserve the root systems intact. The measurements made on some of these plants collected from plots to which no artificial fertilizers were added, are presented in Table I and serve to compare the growth of healthy and diseased plants both above and below the surface of the soil.

TABLE 1.—COMPARATIVE AVERAGE MEASUREMENTS OF DISEASED AND HEALTHY OAT SEEDLINGS AT DIFFERENT AGES

Age in days	Number of plants		Number of leaves	Height of plant	Seminal roots		Nodal roots	
	Healthy	Diseased			Ave. no. per plant	Ave. length	Ave. no. per plant	Ave. length
				cm.		cm.		cm.
18		5	2	9.4	5.0	3.2	2.8	3.0
	15		2	11.7	4.4	7.8	1.9	0.4
27		7	3	10.5	4.7	3.8	4.1	5.3
	5		4	18.5	4.5	9.8	4.0	5.0
35		11	3	10.6	5.0	4.1	3.5	4.5
	3		6	26.0	5.0	12.5	4.0	9.5
43		6	4	10.3	4.5	6.9	3.6	6.4
	2		7	36.5	5.0	15.0	6.0	11.5

In order to compare the root systems of mature plants, excavations were made in the centre of a severely diseased patch and in a healthy field nearby where conditions were otherwise similar. It was found that the roots of diseased plants never attain any great length. The following description of a typically diseased root system was written at the time the plants were excavated:

"August 10. Total length of seminal root system, 4½ inches, cortex mostly missing but stele apparently intact. There are five roots, extensively branched with short, swollen, stubby, matted laterals, and with many nematode cysts adhering or black scars indicating where they have dropped off.

The first nodal roots are about the same length and are similarly clubbed and distorted.

The main bulk of the root system consists of six secondaries and their numerous short, matted branches, with a total length of about ten inches and from 1/25 to 1/50 of the bulk of a normal root system. There are a great many brown cysts adhering to the secondary roots, and in addition, there are numerous red and brown fungal lesions. The roots are all in the surface soil and do not extend below plow depth."

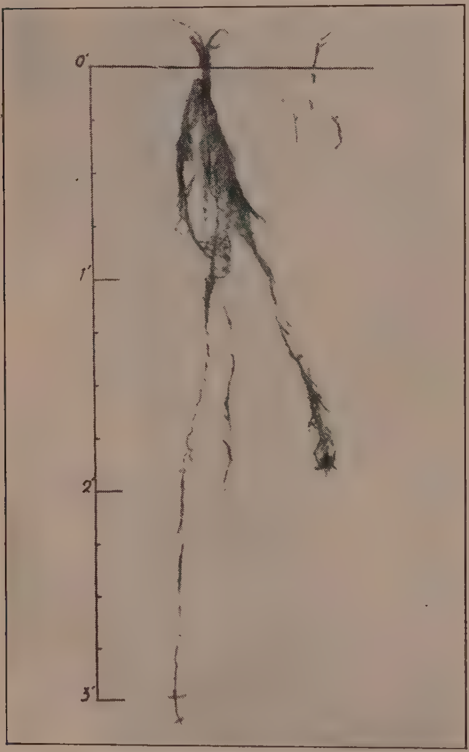

FIGURE 4.—Pressed specimens of typically healthy and diseased mature oat root systems, excavated August, 1934.

In contrast to this, healthy plants at maturity have sound apparently functional, seminal root systems, which may penetrate to a depth of 14 inches (350 mm.). The secondary roots may attain a depth of over 3 feet with enough of them of sufficient length to provide a good working depth of two feet. The illustration in Figure 4 gives a good idea of the difference in root development.

Barley is seldom so heavily attacked as oats and is hence often able to produce a fair crop. In severe cases, however, the same patchy appearance, coupled with extreme weediness, is seen in the field. The young seedlings are stunted and the roots are short and distorted though not always so matted as those of oats. The leaves of the diseased barley plants invariably turn yellow rather than red, but they wither and drop in about the same length of time.

ETIOLOGY

Nematodes were first observed during the summer of 1933, and in a preliminary survey of fifteen fields, cysts were found on the roots of stunted plants in all cases. Since in addition large numbers of fungal lesions were found on the roots of all diseased plants, it was felt advisable to investigate the fungus flora of these roots. Accordingly, a number of isolations were made and pure cultures secured. Certain of those which appeared most consistently were then selected for pathogenicity tests.

Preliminary *in vitro* tests were made upon oat seedlings grown aseptically in flasks of Pfeffer agar. Inoculations were made, using two species of *Pythium*, two strains of *Ramularia* and one strain of *Fusarium*. All five were able quite quickly to penetrate and cause lesions upon the oat roots under the conditions of the experiment.

Further pathogenicity tests were then attempted, using soil brought from the affected area, steam sterilized and placed in pots on the greenhouse bench. Sufficient inoculum was obtained by growing pure cultures of the above fungi on autoclaved flasks of oats; this was added to the soil at the time the seeds were sown. It was found that the *Pythium* species were capable of giving a quite definite check to the development of the root system. The strains of *Ramularia* and *Fusarium* were able to produce numerous lesions on the roots, somewhat similar to those observed in the field. All five fungi were easily re-isolated from these diseased roots. In no case, however, did the general appearance of the root system, or the growth habit of the aerial parts of the plants, duplicate the symptoms observed in the field.

In addition to the pathogenicity tests with the various fungi isolated from oat roots, an attempt was made to determine which parasite, or parasites, first effected an entry into the roots. Two sets of greenhouse experiments were included in this series: one in which the soil from an infested field was placed in pots on the bench under ordinary conditions, and one in which the soil was placed in metal containers immersed in Wisconsin constant temperature tanks. It was thus possible to hold the latter at different temperatures and to keep them adjusted to various soil moistures. Oats were planted and periodic examinations of the roots were made from the time of germination. The first fungus to gain entrance to the oat roots, except in very dry soil, was always *Asterocystis radicis*, which has been reported by Vanterpool (*16*) as being in constant association with diseased oat roots. In moist soil (over 30% based on constant weight at 90° C.) it was usually in advance of the nematode but in moderately dry soil (19%–26%) the nematode was always the first parasite to enter the root tips, and in very dry soils (12%–15%) *Asterocystis* was not found although nematodes were in abundance. In moist soils the second series of invaders were usually *Pythium* sp. and in the dryer soils, *Fusarium* or other Fungi Imperfecti. It was only in the dryer soils that anything resembling the conditions of the roots in the field could be demonstrated. Here the roots were short and stubby, and after a month were found to have fairly large numbers of nematode cysts adhering.

In May 1934, a similar series of observations was carried out in the field. The soil was at no time found to contain as much moisture as was maintained in the wettest greenhouse conditions, but ran from 20%–24%. On the third day after planting, sprouted oats were dug up and examined microscopically for parasites. Nematodes were again found to be the first entrants into young oat roots, often being found before the radicle was more than one-quarter of an inch long. At this time no fungus of any kind could be seen in the roots. Out of about fifty roots from an infested field examined on the fourteenth day after planting, all contained nematodes but in only one was any fungus seen, which in this case was a *Pythium*. Oat roots in which no nematodes were found did not branch

early but continued to grow downward for several inches, while roots only half an inch long which had been invaded by nematodes had already put forth from six to twelve lateral branches (Plate I, 4).

LIFE HISTORY OF *HETERODERA SCHACHTII*

Nematode larvae are easily demonstrated in the root tips of infested seedlings by crushing the unstained tissue in a drop of water on a microscope slide, and examining under low power. In order to determine more accurately the number and the position of the worms in the tissue, some method of staining had to be employed. It was found that boiling for a minute in lactophenol to which had been added either cotton blue or acid fuchsin gave excellent results. By this means a total of thirty-three nematodes were found in one root which was less than 1.5 cm. in length, taken from an oat seedling in May, fourteen days after planting. This short root had already ten lateral branches, and all but one of them contained nematodes. The larvae are invariably found with their heads toward the tip of the root (see Plate II, 1). As many as sixteen nematodes have been observed in a single root tip less than two millimeters in length. They seem to prefer the meristematic regions, but are also to be found in small numbers throughout the cortex, but not in the stele.

When first found in the root tips, the larvae are from .55 mm. to .60 mm. in length, with a rather bluntly rounded head containing the bucal spear or stylet which can usually be fairly easily seen (Plate II, 5). The tail in larval stages is pointed. First stage larvae observed when emerging from the eggs and still within the cysts measured .53 mm. to .55 mm. (Plate II, 2). For a period of about three or four weeks the larvae remain typically worm-like (Plate II, 6), though undergoing one moult during this time and increasing somewhat in length and thickness. At about four weeks from the time of entering the root, the nematodes become somewhat flask-shaped bodies in which the adults may be seen. From this time on the development of the two sexes is quite different. By the middle of June, or about five weeks after planting, mature female nematodes may be found as somewhat swollen, curved bodies, partially protruding through the epidermis of the root. Mature males, slightly over 1 mm. long and typically worm-like, were found free in the soil about the roots at the same time. A week later white, lemon shaped, female bodies ranging in size from .6 mm. to .9 mm. long by about .4 mm. to .6 mm. in width were found containing eggs. They are attached to the root by the head end (Plate II, 4), around which is to be seen the remains of the last moulted cuticle (Plate II, 7).

The female nematodes for the most part remained white until well into July when they changed gradually into brown cysts. The eggs (Plate II, 3) average about $115\mu \times 49\mu$ and are at first unsegmented but by August first some of them were observed to contain fully formed larvae though no hatching had taken place. From September till freeze-up, however, there could be obtained from the soil fresh cysts which contained from one to two dozen first stage larvae, as well as others in the act of emerging from the egg. Nematode cysts are easily obtained by flotation or by centrifuging a suspension of soil in water.

In the fall, first stage larvae have been found in the roots of volunteer oats and barley and in fall wheat. Periodic examinations of the roots of fall-sown cereals were made from seeding time in September until freeze-up late in November but no mature female nematodes were found although more time had elapsed since planting than was the case with spring sown grains.

MIGRATION OF LARVAE

In order to test the migratory and infective powers of the nematode, the following preliminary experiment was performed. A wooden box about eight inches in depth from which the bottom had been removed was bedded in the subsoil of a field and divided into two compartments by means of a fine wire screen. Into one compartment was put soil from a badly infested field and into the other was put soil from a field which was known to be free from the disease. Oats were planted in the nematode free soil while the infested soil was left unplanted. In order to provide a control, two other compartments of the same type were provided, in both of which non-infested soil was placed and one of them planted with oats.

No apparent difference in the aerial parts of these two lots of plants could be noted, but when, late in the season, the oats were dug up and examined, it was found that the plants grown in non-infested soil in juxtaposition to infested soil had a moderate number of nematodes attached to the roots, and there was in addition a certain amount of typical root distortion. In the check lot there were no nematodes and no root distortion was found. The distance travelled by the nematodes across non-infested soil was about eight inches. This distance is quite short when compared with the results of similar experiments quoted by Goodey (*6*).

DISPERSAL

In addition to the actual migration of the larvae for short distances, there are other, and perhaps more effective, ways by which the parasite may be spread. The heavy soil is very tenacious and clings to the wheels of carts, implements, tractors, etc., the feet of animals and workers and in this way the parasites may be carried to new fields, and indeed, to entirely new localities. The brown cysts are light and float easily in water and are probably often spread in this way. The most thoroughly infested areas under observation all happen to be within reach of the flood waters of one or two small streams which must have been instrumental in spreading the infestation. Since no soil blowing is ever experienced in the district, wind is probably not an agent of dissemination in this case.

EFFECTS OF LOW TEMPERATURE

It has been mentioned that the infestation was in general not so bad in 1934 as it was in the previous year and a number of observations in the field point to the conclusion that the extremely low temperatures of the previous winter were unfavourable to the nematode. In a number of cases, fields which were total failures in 1933 had only mild or patchy infestations in 1934. In other cases, the infestations were restricted to definite zones or belts. These belts were usually in the lee of a hedge or a fence or in a sheltered hollow and in such a position that heavy snow drifts

FIGURE 5.— Photograph of on oat field on June 12, 1934, showing a belt af diseased plants in the lee of a rail fence which stands just beyond the left of the picture. Note also the two weak drills which did not receive any fertilizer due to the clogging of the fertilizer attachment.

had lain there during the winter. Figure 5 shows a field which was a total failure in 1933 but which is producing a good stand during the current year except for the belt along the left side which lies directly inside, and to the east, of a heavy rail fence. This difference was noticeable all through the season, and root examination showed that nematodes were abundant in this zone while not nearly so many were found in the rest of the field.

HOST RANGE

The Imperial Bureau of Agricultural Parasitology (*9*) lists 13 species of the Gramineae, and Goodey (*6*) lists 14 species which are attacked by *Heterodera schachtii.* During this investigation the mature female cysts have been found attached to the roots of the following plants: Oats, *Avena sativa* L.; wild oats, *Avena fatua* L.; barley, *Hordeum vulgare* L.; six-rowed barley, *Hordeum distichon* L.; wheat, *Triticum vulgare* Vill., both fall and spring sown varieties; speltz, *Triticum spelta* L.; and chess, *Bromus secalinus* L. Of these, wild oats, speltz and chess are not listed in either of the above publications. Up to the present, no plants outside of the grass family have been found to be attacked by this strain of the parasite.

DISTRIBUTION IN RELATION TO SOIL TYPE

During the season of 1934 a complete field-to-field survey was made of the district. The roots of the oat and barley crops were examined for the presence of nematodes and the fields were classified according to the degree of infestation, taking into account both the condition of the crop and the prevalence of nematode cysts on the roots. In South Simcoe county a total of 137 infested spring grain fields were found, located on 74 different farms which are fairly well concentrated within an area of about 30 square miles in the townships of Tecumseth and West Gwillimbury. In addition, two infested fields were found in Uxbridge township in Ontario county. Of the total of 139 infested fields found in 1934, 30 were classed as severely infested, 40 as having medium infestation, and the remaining 69 as only mildly infested.

It is very interesting to note that nematode infestation seems closely correlated with the type of soil. In general, there are only two types of soil in the particular district though in places there is necessarily a transition zone where they grade into one another.

On the hills is found a light, stony or gravelly loam developed on morainic drift. It is naturally well drained and is neutral to alkaline in reaction. It is fairly low in organic matter but moderately well supplied with mineral nutrients. In the lower areas the soil is a silty clay loam. The topography is rolling, giving fair natural drainage. Much of it is underdrained, especially up the hollows and into springy spots. In many places, particularly on the slopes, it has been subject to erosion thus exposing the highly calcarious parent material. However, free lime carbonate occurs consistently even in the surface layers, making it a strongly alkaline soil. The pH is about 8.2 or 8.3. It is fairly well supplied with available nitrogen and potash but it is quite deficient in available phosphorus. It contains a moderate organic matter content. Detailed investigations of both soil types are now in progress and will be reported on later. The accompanying map (Figure 6) shows the distribution of the infested fields in relation to the soil type. Of the 137 fields only seven were found on the lighter soil and none of them were classed as severe. An equal number of infestations were found on transition soils; the remainder, or 90%,

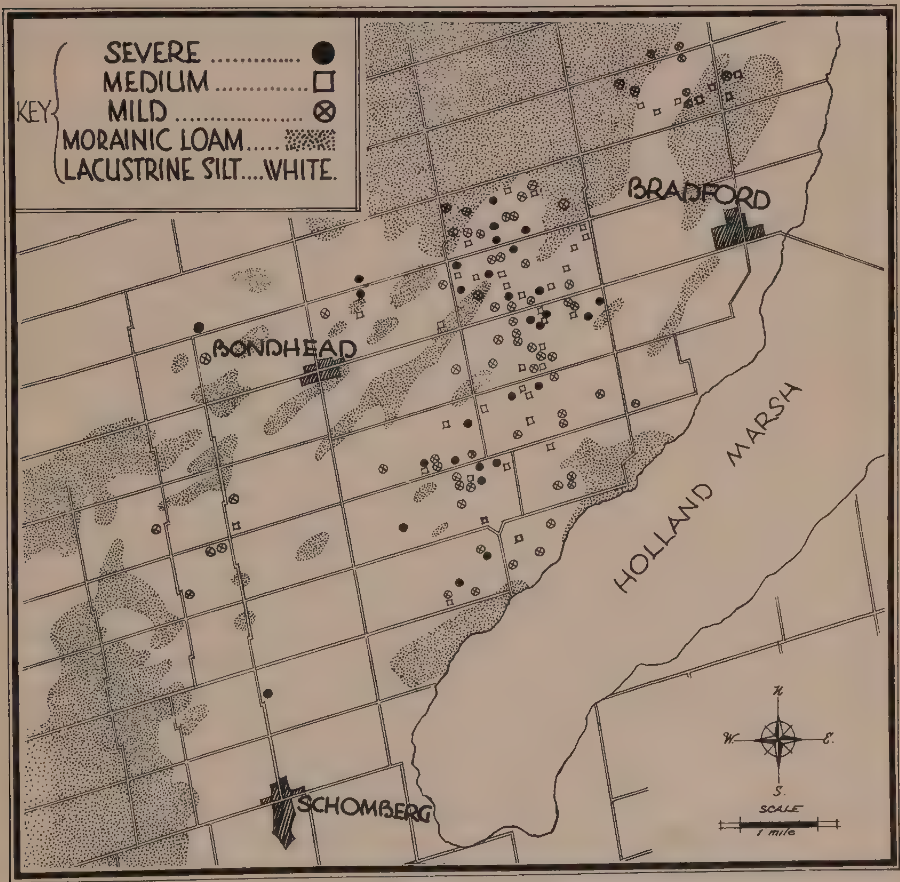

FIGURE 6.—Map of the district in South Simcoe county showing the location of all the grain fields found to be infested with the oat nematode in 1934, together with the distribution of the two chief soil types.

including all the severely infested fields, were found on the silty clay loam of the lower areas.

This type of soil covers a much larger area than that shown in the map. The silt deposits were evidently laid down in a glacial lake which lay between an ice front to the north and the high land to the south and are found almost continuously in an irregular belt extending from Creemore and Collingwood to Peterborough and Rice Lake. Associated sands and loamy soils form intervening areas in the old lake bed, but there are at least 70,000 acres of this particular type of silty clay loam, all of which must be regarded as a potential habitat for the oat nematode.

According to Russell[3] "the soil in the district where we commonly find *Heterodera punctata* Thorne is a park belt medium loam of morainic origin with a pH of about 7.2 to 8.0. The calcareous layer varies in depth in different parts of the district but is usually fairly near the surface." It would seem that this soil is somewhat lighter in texture than that described above.

The field at Glencoe in which Brown (*1*) found the sugar beet nematode was visited by the writers and found to be located on a Brookston clay loam, which is also an alkaline soil.

These facts concerning the types of infested soil are mentioned because in European literature it is usually reported that the lighter types of soil are more favourable to the parasite. According to Goffart[4] the distribution of the oat nematode is generally on morainic light sandy loams and on the lighter marsh soils along the coast. These soils are quite acid, ranging from pH 5.0–6.5. They have not become established on heavy clay soils nor on soils having a strongly alkaline reaction. The reverse would seem to be the case under Ontario conditions, for, while nematodes are found in both a light and a heavy type of soil, they are much more common and troublesome in the latter. It has been noted several times in fields where both types of soil occurred that the infestation was present only in the part of the field located on the heavy soil. The reason for this is not known but it is hoped that detailed investigation of both types of soil may provide a clue.

CONTROL MEASURES

The control of a parasite like *Heterodera schachtii* may be attempted either by direct or indirect methods. Under direct methods are to be included all attempts at soil sterilization. Indirect control methods may have one of the following purposes: (a) the stimulation of the plant to the point where it will produce a crop in spite of the infestation; (b) the elimination of the pathogen by dropping all susceptible crops from the rotation for a sufficient length of time; (c) the production of resistant varieties.

FIELD EXPERIMENTS

A. Chemical Disinfectants

The effectiveness of some of the cheaper substances, which have at various times been recommended as soil disinfectants, was tested in an infested field. A number of 1/100 acre plots were laid out in such a way

[3] In a personal communication of July 1934.

[4] In a personal communication of December 1934.

that each treated plot was provided with two adjacent untreated controls. The following treatments were carried out in duplicate.

Sulphur, 500 lbs. per acre and 1000 lbs. per acre.
Formaldehyde, $\frac{1}{4}\%$, $\frac{1}{2}\%$ and 1%; .75 qts. per sq. ft.
Acetic acid, 1.2% and 2.4%; .75 qts per sq. ft.
Pyroligneous acid, 1.5% and 3% .75 qts per sq. ft.

In addition, a commercial product containing cresylic acid of an unknown strength was used at the rate recommended by its manufacturer.

The field to which these treatments were applied turned out to be only mildly infested over most of its area and so produced a very fair crop. The application of sulphur failed to make any difference in the degree of nematode infestation as compared with the adjoining check plots. It also failed to destroy the strongly alkaline soil reaction. It had, especially in the case of the heavier applications, a distinctly detrimental effect upon the growth of the plants themselves.

There was no significant difference in the infestation in the 1% formalin plots and none at all in the case of the other treatments used. Even in the case of the 2.4% acetic acid where the ground was white with the deposit of calcium acetate, the soil reaction still remained strongly alkaline.

B. Fertilizer Tests

During the season of 1934, rather comprehensive fertilizer experiments were carried out on fields in the infested area in order to see if the seedling plants could be so stimulated that they would be able to overcome the attack of soil inhabiting parasites. The experiments were not designed as yield tests and hence were not replicated. Because of the patchy nature of the infestation, large plots of approximately one acre were used in the hope that several badly infested patches would be included in each plot. The following set of treatments was laid down in each of two fields in the area, the two farms being about four miles distant from one another.

10 tons per acre stable manure
20 tons per acre stable manure
400 lbs. per acre 2-12-6 fertilizer
250 lbs. per acre 20% superphosphate
50 lbs. per acre muriate of potash
40 lbs. per acre sulphate of ammonia
400 lbs. per acre 0-12-6 fertilizer
400 lbs. per acre 2-12-0 fertilizer
400 lbs. per acre 2-0-6 fertilizer

Three check plots were also provided in each field. The fertilizers were all hand mixed and applied with a combination grain and fertilizer drill. The single chemicals were mixed with an adequate amount of sand filler and applied in the same way.

One of these fields was plowed up about the middle of June because it was by that time, evidently, the most uniformly badly infested field in the district, and the weeds had obtained such a start that it was in many places almost impossible to see the oat plants. The other field was seeded down to sweet clover and was not plowed up, but the badly infested areas, which included about half the field, were cut over early in July in order to prevent the weed crop from going to seed.

The field which turned out to be so uniformly infested was sown on May 11 and was plowed under on June 14. At that time complete notes were taken and a number of plants were collected from each plot, care being taken to preserve the complete root system of each seedling. The following table compares the averages of the measurements made on this collection together with those of healthy control plants of the same age obtained from an adjoining farm.

Table 2.—The effect of fertilizer treatments upon the growth of oat seedlings infected with *Heterodera schachtii*, during the first five weeks

Plot No.	Treatment: Fertilizer used per acre	Number of leaves per plant	Height of plant in cm.	Number of seminal roots	Length of seminal roots in cm.	Number of nodal roots	Length of nodal roots in cm.
0	Healthy control	6.0	26.0	5.0	12.5	4.0	9.5
1	Diseased control	3.0	10.6	5.0	4.1	3.5	4.5
2	10 tons stable manure	3.4	12.4	4.8	5.8	4.8	5.9
3	20 tons stable manure	4.0	15.5	4.0	6.5	3.8	4.9
4	400 lbs. 2-12-6	4.0	17.0	4.6	6.5	4.0	3.5
5	250 lbs. superphosphate	4.0	16.3	3.8	6.8	3.5	5.4
6	50 lbs. muriate of potash	3.6	11.6	3.2	6.7	3.0	4.4
7	40 lbs. ammonium sulphate	2.7	11.4	3.6	2.9	4.3	3.1
8	400 lbs. 0-12-6	4.0	17.3	4.5	4.8	5.5	4.7
9	400 lbs. 2-12-0	3.1	10.5	4.4	1.0	2.2	1.7
10	400 lbs. 2-0-6	4.0	15.0	4.0	5.3	4.0	4.3

It will be seen immediately that no fertilizer treatment is able to produce plants comparable to the healthy controls. In general the best response was obtained from the use of complete fertilizer although superphosphate alone gave almost equal results. No benefit was received from the application of ammonium sulphate, and very little from muriate of potash. It is interesting to note that the plot receiving the combination of ammonium sulphate and superphosphate was by all odds the poorest looking plot in either of the experimental fields. The leaf area on almost all of the plants was completely destroyed and many of the plants, especially in the heavily infested field, died outright. The experiment illustrates the need for research into the effects of various commercial fertilizer substances when applied to such types of soil, entirely apart from the complicating factors arising from a diseased condition.

In view of the pronounced phosphorus deficiency found in this type of soil, and the ability of calcareous soils in general to "fix" phosphorus in an unavailable form, another experiment was planned in the hope of finding some level at which the beneficial effects of available phosphorus would offset the attack of the root parasites. In a third experimental field a series of varying amounts of superphosphate were applied, ranging from 50 lbs. to 1500 lbs. per acre.

In general the degree of infestation made more difference to the appearance of the field than did the amount of fertilizer applied. In badly infested patches the highly fertilized portions were little better than the

unfertilized checks; while, where there was less infestation, a considerable improvement could be noticed. The infestation of this field was of such a patchy nature that comparative data could not be secured, but from a visual examination there was certainly no doubt that superphosphate was extremely beneficial to the oat crop, especially in the matter of hastening maturity. No amount of superphosphate was able to promote root growth to the extent that the effects of severe nematode infestation could be overcome; there was no indication that superphosphate had any effect upon the nematode population, the most heavily infested spot in the field, and the one in which leaf symptoms first appeared, had received 1500 lbs. of superphosphate per acre.

It had been previously found that the tissues of diseased plants were notably deficient in phosphorous, using the method of Spurway (*13*). In unfertilized fields diseased plants had from 0–½ p.p.m. and it was thought that the leaf symptoms might in some way be connected with this deficiency. Accordingly, tissue tests were made on plants grown in the fertilized plots. The amount of available phosphorus supplied was reflected in the tissue tests. Healthy control plants gave a test of ½–1 p.p.m. while diseased control plants had only a trace. On the other hand diseased plants which had received small amounts of superphosphate contained from 2–2½ p.p.m. and those in the heavily fertilized plots had from 2½–5 p.p.m. The plants were able to absorb available phosphorous from the soil in spite of the infestation of nematodes in the roots.

The available evidence does not indicate that the foliage symptoms are due to a lack of essential mineral nutrients. It does suggest, however, that the major factor in the development of the diseased condition is an inability to secure adequate amounts of water. The appearance of the plants and the special severity of the disease during periods of drought are facts supporting this hypothesis.

DISCUSSION OF CONTROL MEASURES

Direct control methods do not seem to be practicable although numerous investigators have for years pursued this line of research. True, certain substances such as carbon disulphide and calcium cyanide will effect a control if applied in large quantities but the cost is prohibitive. Goffart (*5*) estimated that it would cost approximately $1,500.00 per acre to rid the soil of nematodes by means of calcium cyanide. Guba (*7*) used carbon disulphide emulsion against *Heterodera marioni* and on the basis of his figures it would cost about $485 per acre. A great many other chemicals have been used against various soil borne pathogens, among them are acetic acid, sulphuric acid, pyroligneous acid, cresylic acid, sulphur and formalin. The use of acid substances on a highly alkaline soil such as that found in the area is apparently of no avail; the heavy texture of the soil also makes it difficult to secure proper distribution of the materials in the soil. While admittedly it is not economically possible to treat large areas, the subject is worthy of further study. If some efficaceous treatment could be devised, it would be applicable in the case of a newly invaded small patch and thus avoid the infestation of a whole field.

The use of trap crops was devised in Germany against the sugar beet nematode many years ago. The method consisted in sowing an early

crop of rape or some other susceptible crop which was plowed up in a few weeks. Though some measure of control was obtained, it has not always been successful. The plowing up of infested oat fields early in June is probably good practice, not only to get rid of the weeds, but to expose the roots containing the immature larvae to the heat of the sun. Since there is apparently only one generation of nematodes during the growing season of the oat crop, this procedure might be of value in their control if done early enough. It is too late to plant oats or barley again but buckwheat may be planted or the fallow may be worked up during the summer.

Indirect control measures are proabaly more practicable and many different treatments are mentioned. Davidson (*2*) recommends early sowing, cultivation, land packing and the application of superphosphate to promote root development. Goodey (*6*) mentions the use of nitrogenous manures. Goffart (*5*) advocates shallow plowing and the use of plenty of seed to lessen the danger of attack, and warns that nitrogenous substances such as stable manure may also stimulate the parasite. Our own observations seem to indicate that the supplying of adequate available soil nutrients is not sufficient to enable the plant to overcome the attack. On the other hand, plants growing in soil tanks having adequate moisture, deep sown plants, and those growing in the packed soil of tractor wheel marks were all stimulated because of extra available moisture.

On the whole, the most promising methods of control seem to be crop rotation and the development of resistant varieties. So far no one has found any variety of oats which is resistant, but Nilsson-Ehle (*11*) reports that some varieties of barley are more resistant than others. Crop rotations of course, depend upon the host range of the parasite and upon the length of time it can persist in the absence of suitable hosts. The race which is present in Ontario is apparently found only on members of the Gramineae. As to the length of time the nematodes will remain in the soil, Fuchs (*3*) and Thorne (*14*) report that the cysts contain viable eggs for five to six years. Our own observations have shown that an interval of four years was sufficient to produce a healthy oat crop, but there were still a few larvae found to be present in the roots of some of the plants. We have not found nematodes below plow depth and that is undoubtedly the reason that severe winter frosts are able to affect them. The practice of shallow plowing and ridging the soil should exert a beneficial effect by allowing the frost to penetrate more thoroughly.

The problem of control is an individual one with each farmer concerned, depending upon whether he has to deal with only one infested field or his whole farm. If it is only a small patch or a single field, it should be seeded down to alfalfa and left for at least five years. However, few farmers can afford to do this with their whole farm, nor is it possible for us to issue blanket recommendations as to the best rotation to follow, since the need varies with the plan of farming being followed. The rotation should be five years or more in length on an infested farm; the acreage of spring grains msut be sharply curtailed and other crops such as roots, corn, beans, soy beans, clover and alfalfa should be substituted. Buckwheat is found useful in many cases. Field peas cannot be recommended in the district because of the destructive attacks of root-rotting fungi. The growing of winter wheat should be limited as it serves to propagate

the parasite, though not itself seriously affected. Finally, every effort should be made to get rid of wild oats in order that the nematodes may not be able to complete their development while non-susceptible crops are being grown.

CONCLUSIONS

The presence of the oat race of *Heterodera schachtii* in Ontario is to be regarded as a distinct menace to the growing of cereals over large areas in Ontario though, fortunately, the correlation of the infestation with one type of soil may be a factor in inhibiting its spread. Farmers and agricultural workers should be on the lookout for new cases of infestation and every necessary assistance should be rendered to farmers in infested areas in their efforts to stamp out the parasite.

Although the place and date of the first infestation cannot be determined, the parasite is clearly an introduction. Since it now occurs over an area of at least thirty square miles, it must have been present for a considerable numer of years, even before certain farms began to experience consistent crop failures about ten years ago.

That *Heterodera schachtii* is to be regarded as the major causal factor of the "seedling disease" and subsequent crop failure, is pretty well established by the following observations. All the plants found to exhibit any foliage symptoms of the seedling disease were found to have also stunted and distorted root systems. In these poor root systems are to be found nematode larvae and sometimes various root rotting fungi. There was, however, no consistent association of any one fungus pathogen, and more over, in the early stages it was usual to find the distorted roots containing nematodes with no fungi present. The same fungi were isolated from lesioned roots not typically distorted, while in no case were distorted roots found without nematodes. The description of the disease, though differing in slight details, is similar to that described by European and Australian workers, and, together with the identification of the nematode, there is sufficient evidence to warrant the conclusion that we are dealing with a disease of cereals caused by the presence of the nematode *Heterodera schachtii*.

The presence of root-rotting fungi, especially in the later stages of the disease, must not be minimized or overlooked, for the nematode has apparently completed its work about halfway through the growing season. It is probable, therefore, that the true interpretation of a complete crop failure involves the influence of a number of secondary invaders coincident upon a root system already greatly disturbed by nematode infestation.

Summary

1. The presence of the oat race of the nematode *Heterodera schachtii* is reported for the first time in North America.

2. A description of the symptoms and effects of infestation upon the oat and barley crops is given, based upon two years' observation in the field.

3. A preliminary account of the life history of *Heterodera schachtii* under Ontario conditions is presented together with certain observations upon the spread and persistence of the organism in the soil.

4. A complete survey has been made of the infested district and a map prepared showing a correlation between nematode infestation and type of soil.

5. The chief methods of control together with their underlying principles are discussed, and their probable effectiveness is indicated from experiment and observation in the field.

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Résumé

Maladies des plantules d'avoine dans l'Ontario. 1. Le nématode de l'avoine Heterodera Schachtii Schm. D. F. Putnam et L. J. Chapman, Institut des recherches de l'Ontario, Toronto, Ont.

La présence du nématode *Heterodera schachtii* de la racine de l'avoine est signalée pour la première fois dans l'Amérique du Nord. Il est donné une description des symptômes et des effets de la présence de ce parasite sur les avoines et les orges, basée sur deux années d'observations dans le champ, ainsi qu'un compte-rendu préliminaire du cycle évolutif du *Heterodera schachtii*, dans les conditions de l'Ontario, et certaines observations sur la propagation et la persistance de l'organisme dans le sol. Une inspection complète du district infesté a été faite et une carte a été préparée, montrant la corrélation entre l'invasion de nématodes et le type de sols. Les principaux moyens de lutte ainsi que les principes sur lesquels ils s'appuient sont discutés, de même que leurs effets probables, basés sur les expériences et les observations faites dans le champ.

98159—5½

THE GROWTH OF TURNIPS IN ARTIFICIAL CULTURES[1]

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During the last ten years a wide range of nutritional studies has been made by this laboratory with various horticultural crop plants, employing the sand-culture method. At an early stage it was recognized that lack or deficiency of minor elements such as boron and manganese might confuse or upset the results secured from known variants, so that minute amounts of these two elements have been employed in the basic culture solution (*2*). Knowledge of safe concentrations of these two elements in the culture solution for the plants studied was secured from the literature, but no results had been obtained by the authors concerning optimum concentrations, toxic concentrations, or the symptomatic effects brought about by deficiencies or excesses. As a preliminary to mineral nitrogen studies with the turnip it was considered advisable to first test the suitability of the basic culture solution for growing turnips and at the same time gain symptomatic information regarding the effect of deficiency or excess of the element boron as well as its effect on the intake and utilization of other mineral elements.

Warington (*6*) showed that broad beans attained full development only when a trace of boron was given. The best results were obtained with quantities of the order of one part of $H_3 BO_3$ per million of the culture solution; amounts greater than 1 in 5,000 were harmful. Sommer and Sorokin (*5*) studied the effect of the absence of boron on the growth and development of *Pisum sativum* in culture solutions. They found that the meristematic region of root tips grown without boron becomes abnormal. The cells cease dividing normally and existing cells undergo premature development or pathological changes; in a general way the absence of boron causes a disturbance in the regulation of growth and development. Johnston and Dore (*3*) found that the element boron in a concentration of approximately 0.5 ppm. was necessary for the normal growth and development of the tomato. In the absence of this element four distinct types of injury occurred; death of the terminal growing point of stem; breaking down of the conducting tissues in the stem; characteristic brittleness of stem and petiole; and roots of extremely poor growth and of a brownish unhealthy colour. A concentration of 5.5 ppm. boron in the nutrient solution was toxic to tomato plants.

McHargue and Calfee (*4*) report that boron is essential for the growth of lettuce and that when it is excluded from the nutrient solution, a severe deficiency disease results which is characterized by malformation of the more rapidly growing leaves, spotting and browning of the leaf tips, and death of the growing point of the plant. The optimum concentration of boron was found to be 0.7 ppm. while concentrations from 1.2 to 2.5 ppm. produced increasing toxicity.

Brandenburg (*1*) working with sugar beets in sand found that as high as 30 mg. boric acid could be added to a ten litre pot without causing

[1] Contribution from the laboratory of Plant Physiology, Horticultural Division.
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any signs of toxicity due to excess boron and that even this application gave very weak symptoms of boron deficiency after a prolonged period of growth. Weight and per cent sugar content were directly proportional to the boron supply. Analysis showed lower boron content in diseased than in healthy plants with a remarkably high ash content in diseased beets.

MATERIALS AND METHODS

Two varieties of turnips were employed: Canadian Gem, a Swede grown to a considerable extent for table use; and Ditmar Swede, a field variety. Seeds were germinated in greenhouse soil and pricked out into two-inch pots in soil where they were held for a short time. The soil was then washed off the roots and the plants transferred to washed sandstone in four-inch clay pots the walls of which had been coated with wax. After the plants had made sufficient root growth, they were transferred to glazed stone jars of three gallon capacity containing sand-stone. Bakers c.p. chemicals were used throughout for the making up of culture solutions. No attempt was made to repurify the c.p. chemicals used in this experiment; the failure of plants to develop in solutions made with them but without the addition of boron indicated this was unnecessary. Due to the fact that the plants were started in soil and the chemical salts not repurified the appearance of boron deficient symptoms were probably delayed but since turnips have a relatively large capacity for the element boron the purpose of the experiment was not defeated.

The deficient boron nutrient solution employed as a basic formula for all plants is given below.

Stock nutrient solutions

$MgSO_4, 7H_2O$	140 gms. in 2,000 cc. water.
$KH_2\ PO_4$	70 gms. in 2,000 cc. water.
$Ca\ Cl_2$	150 gms. in 2,000 cc. water.
$NH_4\ NO_3$	360 gms. in 4,000 cc. water.
$MnSO_4 . 2H_2O$	1 gm. in 2,000 cc. water.
$K\ NO_3$	50 gms. in 2,000 cc. water.

From these stock solutions the nutrient solution was made up as follows:

Amount of stock solution in 2,000 cc. water.

$MgSO_4, 7H_2O$	28 cc.
$KH_2\ PO_4$	31 cc.
$Ca\ Cl_2$	29 cc.
KNO_3	80 cc.
$NH_4\ NO_3$	81 cc.
$MnSO_4 . 2H_2O$	2.1 cc.
$FeCl_3$	10 cc. of 0.5% solution.

Five different boron treatments were employed, each treatment consisting of five plants. Boron was supplied in the form of boric acid.

I. Boron to be deficient.
II. Boron concentration of solution 0.25 ppm.
III. Boron concentration of solution 0.5 ppm.
IV. Boron concentration of solution 1.0 ppm.
V. Boron concentration of solution 1.5 ppm.

Parts per million of the elements in the nutrient solution

Series	N	P	K	Mg.	Ca.	S	Mn.	B	Fe.
1	1878	122.8	930	96.4	400	127	0.19	000	3.44
2	1878	122.8	930	96.4	400	127	0.19	0.25	3.44
3	1878	122.8	930	96.4	400	127	0.19	0.50	3.44
4	1878	122.8	930	96.4	400	127	0.19	1.00	3.44
5	1878	122.8	930	96.4	400	127	0.19	1.50	3.44

Solutions were fed once a week at the rate of 200 cc. per pot. During the growth of the plants each pot received eighteen applications of nutrient solution so that the total amount of boric acid fed per pot is as follows:

Series		Series	
1	0	4	20.16 mg.
2	5.04 mg.	5	30.24 mg.
3	10.08 mg.		

RESULTS

Growth Characteristics

After being subjected to these treatments for a period of six weeks, series No. 1 receiving no boron showed definite signs of boron deficiency. The injury commenced as a light yellow marginal colouring of the leaves in time involving large areas (Figure 1). The region next to the veins remained green the longest. In some cases the under sides of the leaves were markedly reddish-purple. At this time the only other treatment exhibiting deficiency symptoms was series 2 which showed slight marginal yellowing on a few of the bottom leaves. After a period of ten weeks two of the plants in series 1 were completely dead with the other plants stunted,

FIGURE 1. Leaf from plant receiving 1.5 ppm. boron—normal appearance. Right.—Leaf from plant lacking boron. Showing marginal yellowing in the initial stages of boron deficiency.

FIGURE 2. Plant grown with boron lacking solution.

yellowing of the leaf margins, leaves curled, white scorched, shrivelled, dying from the margin and growing point (see Figures 2 and 3). Leaf petioles had dried up, corky growth on both inner edges sometimes advancing into the midrib. The roots were small and shrivelled or rotting at their juncture with the top. In series 2 receiving 0.25 ppm. of boron, the plants had made fairly good growth although many of the leaves were noticeably curled, and yellowed at the margins with distinct purple pigmentation. A considerable proportion of the leaves were dying. Roots were medium in size (see Figure 4.) Plants receiving 0.5 ppm. of boron were considerably more vigorous, and larger in size with better foliage than the previous two treatments. However, foliage injury still persisted of the same character but reduced in severity. Roots were large in size. Plants receiving 1 and 1.5 ppm. of boron were large and vigorous with very large roots. A very small amount of foliage injury still persisted. There was a gradual increase in vigour, size of roots and decrease of foliage injury as the concentration of boron in the nutrient solution was increased, until in plants receiving 1.0 and 1.5 parts per million plants were almost normally healthy in appearance (see Figure 3).

FIGURE 3. Left.—Boron concentration 1 ppm. Centre.—.25 ppm boron. Right.—Lacking boron.

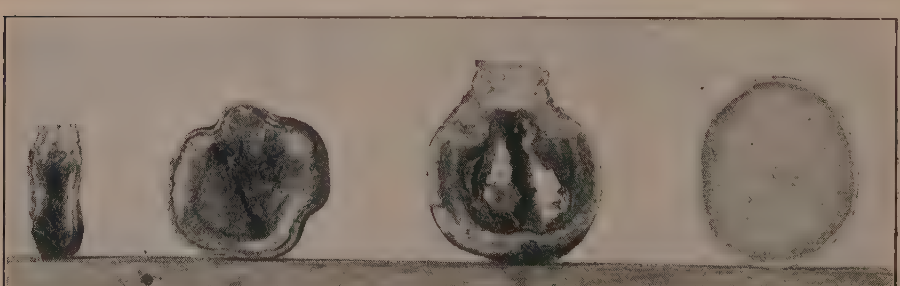
0 ppm. .25 ppm. .50 ppm. 1.0 ppm. 1.5 ppm.

Figure 4. Showing root development under the range of boron concentrations employed.

Boron treatment	Canadian Gem		Ditmar Swede	
	Average root diameter in inches	Average weight in ounces	Average root diameter in inches	Average weight in ounces
Deficient	0.6 (2 dead)	2.0	1.8	5.5
0.25 ppm.	3.2	16.2	3.7	30.0
0.50 ppm.	4.1	32.0	4.4	31.0
1.00 ppm.	3.8	35.4	4.5	44.8
1.50 ppm.	4.1	29.0	4.56	50.7

Root Formation and Characteristics

Root formation in plants receiving deficient boron nutrient solution was practically absent. Two of the five plants in the variety Canadian Gem and three plants in the variety Ditmar Swede rotted off at the junction of top and root and the small root already formed, decayed. Plants that survived formed but very small roots which were affected with hollow heart (see Figures 4 and 5). When 0.25 ppm. of boron were supplied in the nutrient solution plants were able to form roots of fairly good size though still considerably smaller than those procured when the boron



0 ppm. .25 ppm. .50 ppm. 1.5 ppm.

FIGURE 5. Showing cross-section of roots produced under the different boron concentrations. One root from series receiving 1.5 ppm of boron entirely free from disorder.

concentration was increased. However, when the roots from this treatment were cut open they were all found to be seriously affected with hollow heart. In the variety Canadian Gem, four of the five roots were severely affected with hollow heart, while in the variety Ditmar Swede, three of the roots were hollow hearted.

The next highest concentration of boron, 0.5 ppm., produced roots still considerably greater in size. In both varieties four of the roots were severely affected with hollow heart while the fifth root in the case of the variety Ditmar Swede, had a narrow zone of sound flesh around the perimeter of the root.

In series 4 receiving 1 ppm. of boron hollow heart was entirely absent. Although every root showed some sign of the trouble, the area affected was reduced. In both varieties, two roots had a narrow zone of sound flesh around the perimeter with the other three roots having the upper half of the flesh healthy.

In the highest concentration of boron employed, there was a still further reduction in the severity of the trouble. One root in each variety was entirely free from any sign of disorder while in the other roots the affected flesh was confined to a small area at the centre or at the base.

TABLE 1.—ASH ANALYSES WERE MADE OF THE LEAVES AND THE ROOTS, THE RESULTS OF WHICH ARE TABULATED BELOW

Treatment	% Dry matter	Carbonate ash as % Dry matter	Ash constituents as % Dry matter							
			SiO_2	Fe_2O_3	Al_2O_3	Mn_3O_4	K_2O	CaO	MgO	P_2O_5
Canadian Gem Leaves										
0.25 ppm. boron	8.29	8.37	0.17	0.06	0.06	0.005	1.85	1.64	0.61	1.11
1.5 ppm. boron	10.14	7.62	0.22	0.07	0.01	0.01	1.64	1.81	0.62	1.00
Ditmar Swede Leaves										
0.25 ppm. boron	9.55	8.14	0.30	0.09	—	0.01	2.32	1.62	0.54	1.07
1.5 ppm. boron	10.29	7.40	0.31	0.05	0.03	0.003	2.04	1.42	0.58	1.21
Canadian Gem Roots										
0.25 ppm. boron	14.34	7.34	0.42	0.05	0.61	0.002	2.77	0.90	0.38	0.60
1.5 ppm. boron	13.78	4.57	0.11	0.01	0.02	Trace	1.85	0.56	0.21	0.29
Ditmar Swede Roots										
0.25 ppm. boron	10.31	8.96	0.17	0.01	0.03	0.003	3.70	0.98	0.49	0.85
1.5 ppm. boron	13.41	5.45	0.05	0.02	0.02	Trace	2.21	0.72	0.35	0.51

One of the most outstanding features of the analytical data is the very low ash in dry matter of the high boron roots as compared with the low boron roots. These results are similar to those reported by Brandenburg (*1*) in his work with sugar beets.

There is a possible greater concentration of potassium in the leaves when the boron supply is low with a pronounced increase of potassium in the roots when boron is low in both varieties. Analyses of the leaves from the two varieties gives contradictory results for calcium but in the roots a decided reduction of calcium accumulation where boron is fed. Warington (*7*) suggests that some kind of relationship exists between boron and calcium, the exact nature of which is yet undetermined. There does

not appear to be any relationship between the boron supply and the magnesium content of the leaves but where boron is deficient a decided accumulation of magnesium appears evident in the roots. There is also a decided increase in phosphorus accumulation in the low boron roots as compared with those receiving a greater supply. Deficiency of boron causes an accumulation of potassium, phosphorus, magnesium and calcium in the roots.

Boron determinations were made on the roots from these treatments the results of which are tabulated below. These boron figures were supplied through the courtesy of the Chemistry Division, Central Experimental Farm.

Identity—Treatment	Boron as B_2O_3 in ash
Ditmar Swede no boron solution	.005%
Ditmar Swede 0.5 ppm. boron solution	.015%
Ditmar Swede 1.0 ppm. boron solution	.025%
Ditmar Swede 1.5 ppm. boron solution	.035%
Canadian Gem 0.5 ppm. boron solution	.015%
Canadian Gem 1.0 ppm. boron solution	.025%

There is a direct relationship between the amount of boron provided in the nutrient solution and the amount of boron found in the roots. There exists an inverse relationship between the amount of boron found in the roots and the severity of hollow heart. In addition to the close relationship exhibited between the amount of boron fed and the decrease of hollow heart present it is of interest to note that very satisfactory turnips have been grown by the use of culture solutions. In fact, the higher boron concentrations produced turnips quite comparable in size and quality with those produced in the field.

ACKNOWLEDGMENT

Acknowledgments are made to Mr. M. B. Davis, Dominion Horticulturist, at whose suggestion this work was conducted, and whose direction and assistance is much appreciated.

SUMMARY

Employing pot sand cultures boron deficiency was characterized by a marginal yellowing of the foliage followed by a purpling and scorching. Roots were small and shrivelled or rotted at their juncture with the top. Supplying 0.25, 0.50, 1.0 and 1.50 ppm. of boron in the culture solution caused a progressive decrease of foliage injury. An inverse relationship was found between the amount of boron supplied and the occurrence of hollow heart of the roots. An inverse relationship was found between the amount of boron fed and the percentage ash in dry matter of the roots. A direct relationship was found between the amount of boron fed and the amount of boron found in the roots.

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Résumé

POUSSSE DES NAVETS DANS DES CULTURES ARTIFICIELLES. H. Hill et E. P. Grant, Ferms expérimentale centrale, Ottawa, Ont.

Lorsque la culture de navets était faite en pots, dans du sable, le manque de bore se manifestait par un jaunissement marginal du feuillage qui prenait ensuite une apparence violette et brûlée. Les racines étaient petites, racornies ou pourries à leur jonction avec la tige. Un apport de 0.25, 0.50, 1.0 et 1.50 ppm. de bore dans la solution de culture a causé une diminution progressive du désordre. On a constaté qu'il y avait une relation inverse entre la quantité de bore fournie et la présence du cœur creux des racines, de même qu'entre la quantité de bore fournie et le pourcentage de manière minérale dans la matière sèche des racines. Par contre, il y avait relation directe entre la quantité de bore fournie et la quantité de bore trouvée dans les racines.

THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH, DEPARTMENT OF AGRICULTURE, OTTAWA, LARGELY FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada were fractionally higher in March, the index being 72.0 compared with 71.9 in February. There were slight gains in the indexes of vegetable products, of animals and their products, iron and its products, non-metallic minerals and their products, and non-ferrous metals and their products. The most marked recession took place in the fibres, textiles and textile products group. Retail prices were slightly lower, the index being 79.0 compared with 79.1 in February. The index of retail prices of food advanced from 69.2 to 69.5. However, the clothing index fell from 71.3 to 70.3. The index of the value of retail sales advanced from 59.1 in February to 68.2 in March. This gain was not as large as that in the corresponding months of 1934 but this may be accounted for in the fact that Easter sales took place in March last year.

Employment.—The seasonally adjusted index of employment was 98.9 at April 1st, compared with 101.3 at March 1st. The index for manufacturing advanced from 94.4 to 95.1. Employment in mineral production was also slightly higher as was the case in logging.

Physical Volume of Business.—Following substantial gains in January and February the index of the physical volume of business dropped to 94.2 in March. Industrial production fell from 101.1 in February to 93.3. Mineral production showed a fractional decrease. Manufacturing, however, experienced a rather sharp decline from 92.5 to 86.8. Most of the sub-indexes in this group appear to have fallen. Food stuffs declined from 75.9 to 72.5, tobacco from 143.7 to 122.8, and iron and steel production from 92.3 to 90.2. The forestry index was lower but automobile construction was slightly higher than in February. The index of construction registered a decline of from 76.9 to 51.3. Marketings of grain and live stock were higher than in February and cold storage holdings in March were slightly above those of the first of February.

Agricultural Products.—The index of wholesale prices of Canadian farm products has been rising steadily since October, 1934, being 62.7 for March. The index for field products was 56.4 in March compared with 55.7 in February. The average price of No. 1 Northern wheat, cash basis at Fort William and Port Arthur in March, was 81.9 cents as compared with 79.5 in February, 1935, and 66.4 in March, 1934. Prices of other grains were slightly lower than in the previous month. The index of prices of animals and their products advanced from 72.6 in February to 73.3 in March. Average prices for the better grades of all classes of live stock were higher but those of lower grades showed some recession because of larger supplies.

Marketings of grain during the month of March were higher than in the previous month. The total index rose from 55.2 to 57.7, larger shipments of wheat and rye more than offsetting declines in the movement of oats, barley and flax.

The index of live stock marketings rose from 93.4 to 100.0 or the equivalent of the monthly average for 1926. The movement of cattle, calves, and sheep was well above the average but there was a slight recession in hog marketings at inspected plants. Cold storage holdings as already indicated were slightly higher at the beginning of March than at the first of February, increased stocks of butter and mutton being responsible for the higher index.

Conditions in United States.—A moderate increase in acreage of principal farm crops is indicated in reports to the United States Department of Agriculture with about the usual plantings of potatoes, oats, barley, and rye. The total spring wheat acreage planted in 1934 was 9,290,000 acreas whereas intentions this year are estimated at 17,847,000. Other crop acreages are: oats, 39,108,000 compared with

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913	64.0	62.6	56.4	77.0	65.4				
1914	65.5	69.2	64.9	79.0	66.0				
1915	70.4	77.7	76.9	79.2	67.3				
1916	84.3	89.7	88.4	92.3	72.5				
1917	114.3	130.0	134.3	119.6	85.6				
1918	127.4	132.9	132.0	134.7	97.4				
1919	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.8
1923	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.6
1924	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.9
1925	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.6
1926	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933	67.1	51.0	45.8	59.6	77.7	79.7	76.8	105.1	115.4
1934	71.6	59.0	53.9	67.6	78.9	94.2	93.6	88.5	114.2
1934									
Jan.	70.6	55.3	47.9	67.8	78.2	86.8	84.5	48.2	108.1
Feb.	72.1	58.0	49.3	72.5	78.7	86.4	84.0	67.1	98.6
Mar.	72.0	56.5	49.5	68.3	79.9	93.1	92.0	63.8	97.0
Apr.	71.1	55.4	48.7	66.6	79.4	92.6	91.4	56.9	94.5
May	71.1	56.9	51.1	66.5	78.5	99.6	99.4	130.6	102.6
June	72.1	59.3	55.5	65.6	78.2	95.8	95.2	97.2	126.1
July	72.0	60.0	57.8	63.7	78.4	95.7	95.6	148.8	116.3
Aug.	72.3	61.6	60.7	63.1	78.7	99.0	99.8	172.8	114.7
Sept.	72.0	61.3	58.9	65.3	79.0	97.1	97.5	127.7	117.7
Oct.	71.4	60.9	55.3	70.4	79.3	95.8	95.3	61.2	128.8
Nov.	71.2	61.2	55.7	70.4	79.4	96.5	97.0	51.2	130.4
Dec.	71.2	61.6	56.0	70.9	79.0	92.4	91.0	36.0	135.7
1935									
Jan.	71.5	61.4	55.7	71.0	78.9	97.5	97.8	30.6	143.7
Feb.	71.9	62.0	55.7	72.6	79.1	100.6	101.1	62.2	141.2
Mar.	72.0	62.7	56.4	73.3	79.0	94.2	93.3	65.4	143.2

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1933, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1933, p. 33, and Monthly Mimeographs 1934 and 1935.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and price Indexes 1913-1928, pp. 181-185, 290-293. 1926=100.

Prices and Price Indexes 1913-1931, p. 108, and Monthly Mimeographs 1934-1935.

6. Monthly Review of Business Statistics, p. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

30,395,000 last year; barley, 11,954,000 compared with 7,144,000; potatoes, 3,272,000 compared with 3,303,000; tame hay, 53,117,000, compared with 51,495,000, and tobacco 1,511,000 against 1,335,000 in 1934. Indexes of prices of farm products for March show that those of cotton, fruits, truck crops, dairy products, chickens and eggs declined, while those of meat animals advanced. The total index was 108

compared with 111 in February. The index of prices paid by farmers for commodities bought was 128 compared with 127, and the ratio of prices received to prices paid fell from 87 in February to 84 in March. These indexes are based on the average 1910–14.

Urban conditions are somewhat variable. The index of industrial wages in New York State factories was 189 in February compared with 188 in January and 180 in November, 1934. The index of factory employment was 81.9 in March of this year, compared with 81.0 in March, 1934, and the highest point reached since May of last year. Manufacturing production was slightly higher in March this year, the index being 88 compared with 82.0 in March of last year. Mineral production was 95.0 and 100.0 respectively whereas industrial production was 89 compared with 84. The Bureau of Labour index number of wholesale prices was 116 in February. representing a gain of 9 points over that for February, 1934. This index was 115 in January, 1935, but throughout 1934 never rose above 113, which point was reached in September.

LA SITUATION ÉCONOMIQUE

PRÉPARÉ PAR LA DIVISION DE L'ÉCONOMIE AGRICOLE, MINISTÈRE DE L'AGRICULTURE, OTTAWA, PRINCIPALEMENT D'APRÈS LES DONNÉES RECUEILLIES PAR LE BUREAU FÉDÉRAL DE LA STATISTIQUE

Les prix du gros au Canada ont remonté d'une fraction en mars; l'indice était à 72·0 contre 71·9 en février. L'indice des produits végétaux, des animaux et de leurs produits, du fer et de ses produits, des minéraux non métalliques et de leurs produits et des métaux non ferreux et de leurs produits s'est un peu relevé. C'est dans le groupe des fibres et des matières textiles que la plus forte régression a été enregistrée. Les prix du détail ont légèrement baissé, l'indice étant à 79·0 contre 79·1 en février. L'indice des prix du détail de la nourriture est monté de 69·2 à 69·5, mais l'indice des vêtements est tombé de 71·3 à 70·3. L'indice de la valeur des ventes au détail, qui était à 59·1 en février, est monté à 68·2 en mars. Ce gain n'est pas aussi fort que pendant les mois correspondants de 1934, peut-être parce que les ventes de Pâques ont eu lieu en mars l'année dernière.

Emploi.—L'indice de l'emploi ajusté pour la saison était à 98·9 au 1er avril contre 101·3 au 1er mars. L'indice pour les manufactures est monté de 94·4 à 95·1. L'emploi dans la production minérale était aussi un peu plus élevé, de même que dans l'industrie du flottage des bois.

Volume physique des affaires.—Après avoir enregistré un gain considérable en janvier et février, l'indice du volume physique des affaires est tombé à 94·2 en mars. La production industrielle, de 101·1 en février, est tombée à 93·3. La production minérale accusait également une baisse fractionnelle. L'industrie manufacturière a subi une assez forte régression; l'indice est tombé de 92·5 à 86·8. La plupart des sous-indices dans ce groupe paraissent avoir reculé. Les denrées alimentaires sont tombées de 75·9 à 72·5, le tabac de 193·7 à 122·8 et la production du fer et de l'acier de 92·3 à 90·2. L'indice des forêts était plus faible, mais la construction des automobiles un peu plus élevée qu'en février. L'indice du bâtiment a enregistré une baisse de 76·9 à 51·3. Les ventes de grains et de bestiaux sur pied étaient plus élevées qu'en février, et les stocks entreposés au froid en mars un peu supérieurs à ceux du 1er février.

Produits agricoles.—L'indice des prix de gros des produits de ferme canadiens n'a cessé de s'élever depuis octobre 1934; il était à 62·7 en mars. L'indice des produits des champs, qui était de 55·7 en février, s'est élevé à 56·4 en mars. En mars, le prix moyen du blé Nord N° 1, base comptant, à Fort William et Port Arthur, était de 81·9 cents, contre 79·5 en février 1935 et 66·4 en mars 1934. Les prix des autres grains étaient un peu plus bas que le mois précédent. L'indice des prix des animaux et de leurs produits est passé de 72·6 en février à 73·3 en mars. Les prix moyens pour les meilleures catégories de toutes les espèces de bestiaux étaient plus élevés, mais ceux des catégories inférieures ont un peu diminué à cause de l'offre plus abondante.

En mars, les ventes de grain ont été plus fortes qu'au cours du mois précédent. L'indice total s'est élevé de 55·2 à 57·7; les expéditions plus fortes de blé et de seigle ont largement couvert la diminution dans les expéditions d'avoine, d'orge et de lin.

L'indice des ventes de bestiaux s'est élevé de 93·4 à 100·0, soit l'équivalent de la moyenne mensuelle pour 1926. Le mouvement des bovins adultes, des veaux et des moutons était bien supérieur à la moyenne, mais il y a eu une légère diminution dans les ventes de porcs aux salaisons inspectées. Comme nous le disions plus haut, les stocks entreposés au froid étaient un peu plus considérables au commencement de mars qu'au 1er février; cette augmentation portait surtout sur les stocks de beurre et de viande de mouton.

Conditions aux Etats-Unis.—Les rapports reçus par le Ministère de l'Agriculture des Etats-Unis signalent une augmentation modérée dans l'étendue des principales récoltes de la ferme; les plantations de pommes de terre, d'avoine, d'orge et de seigle

sont à peu près égales à l'ordinaire. En 1934, les emblavures totales de blé de printemps étaient de 9,290,000 acres, tandis que les prévisions pour cette année sont estimées à 17,847,000 acres. Les étendues des autres récoltes sont les suivantes: avoine, 39,108,000 acres, contre 30,395,000 l'année dernière; orge, 11,954,000 acres contre 7,144,000; pommes de terre, 3,272,000 acres contre 3,303,000; foin cultivé, 53,117,000 acres, contre 51,495,000; tabac, 1,511,000 acres, contre 1,335,000 en 1934. Les indices des prix des produits de la ferme en mars montrent que ceux du coton, des fruits, des légumes potagers, des produits laitiers, des poulets et des œufs ont baissé, tandis que ceux des animaux à viande ont monté. L'indice total était à 108, contre 111 en février. L'indice des prix payés par les cultivateurs pour les marchandises achetées était à 128 contre 127, et la relation entre les prix reçus et les prix payés est descendue de 87 en février à 84 en mars. Ces indices sont basés sur la moyenne de 1910-14.

Les conditions urbaines sont assez variables. En février, l'indice des salaires dans les fabriques de l'état de New York était à 189, contre 188 en janvier et 180 en novembre 1934. L'indice de l'emploi dans les fabriques était à 81·9 en mars de cette année, contre 81·0 en mars 1934; c'est le plus haut point depuis mai de l'année dernière. La production manufacturière était un peu plus élevée en mars cette année; l'indice était à 88 contre 82·0 en mars de l'année dernière. La production minérale était à 95·0 et 100·0, respectivement, tandis que la production industrielle était à 89 contre 84. L'indice des prix de gros du Bureau du Travail était à 116 en février, soit une augmentation de 9 points sur février 1934. Cet indice était à 115 en janvvier 1935, mais au cours de 1934 il n'a jamais dépassé 113, atteint en septembre.